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RELATIONS BETWEEN THE SPECTRA AND OTHER CHARACTERISTICS OF THE STARS.

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It follows from this similarity of mass that we can obtain a very fair estimate of the parallax of any visual binary (called by Doberck the hypothetical parallax) by guessing at its mass, and reversing the familiar relation between mass and parallax. If we assume that the mass of the system is twice that of the Sun (about the average value), our hypothetical parallaxes, as the existing evidence shows, will usually be well within forty per cent of the truth, and the deduced absolute magnitudes of the components will rarely be more than one magnitude in error. We may thus extend our study of the relation between absolute magnitude and spectrum to all the visual binaries for which orbits have been computed. The hypothetical absolute magnitudes which we will obtain for them will indeed be somewhat in error, owing to the differences in their masses; but, for our present purpose, the hypothetical values are actually more useful than the true values would be. This sounds remarkable; but it is easy to show that, if we assume that the brighter components of the systems have all the same mass, (say that of the Sun), the resulting hypothetical absolute magnitudes will be the actual absolute magnitudes of stars identical in density and surface brightness with the real stars, but all of the assumed mass. In other words, the effects of differences of mass among the stars are eliminated from these hypothetical absolute magnitudes, leaving only those of differences in density and surface brightness. (This is simply a statement in different form of a theorem which has been known for many years). It is therefore desirable to extend our study to as many binary stars as possible. The number for which orbits have been computed is

relatively small; but by a simple statistical process we may include all those pairs which are known to be really physically connected, however slow their relative motion may be.*

Consider any pair of stars, of combined mass m times that of the Sun, at a distance apart of r astronomical units, and with a relative velocity of v astronomical units per year. By gravitational theory, we have

$$v^2 r = (2\pi)^2 m \left(2 - \frac{r}{a}\right) = 39.7\, m \left(2 - \frac{r}{a}\right),$$

where a is the semi-major axis of the orbit. Now let π be the parallax of the system, s the observed distance in seconds of arc, w the observed relative motion in seconds of arc per year, and i_1 and i_2 the angles which r and v make with the line of sight. Then $s = r\pi \sin i_1$, $w = v\pi \sin i_2$, and our equation becomes

$$sw^2 = 39.7\, \pi^3 m \sin i_1 \sin^2 i_2 \left(2 - \frac{r}{a}\right).$$

In the individual case, the last three factors of the second member are unknown, and we are no wiser than at the start; but the average value which their product should have, in a large number of cases, and the percentage of these cases, in which it should lie within any given limits, may be computed on the principles of geometrical probability. It is thus found that the formula $\pi^3 = \frac{sw^2}{14.6\, m}$ gives values for the hypothetical parallax whose average for a large number of cases will be correct, and that, while in individual cases these values will be too large or too small, half of them will be within 19 per cent of the true values, and the numbers of larger errors will fall off in very nearly the manner corresponding to this probable error. If we compute absolute magnitudes from these parallaxes, their average for all the stars will be a little too bright, since the cases in which the computed parallax comes out too small have more influence than those in which it is too large. This may be allowed for by adding $0^m.15$ to all the hypothetical magnitudes so computed,—an amount almost negligibly small for our present purpose.

* An outline of this method was given by the speaker at the meeting of the Astronomical and Astrophysical Society of America at Ottawa, 1911 August 25, and published in Science, N. S., Vol. 34, pp. 523-525, 1911 October 20. A similar method was worked out quite independently and almost simultaneously by Hertzsprung, and published in A. N. 4543, 1911 Dec. 19, (the date of writing being 1911 October 11).

We thus obtain a series of hypothetical absolute magnitudes whose average for a large number of cases will be correct. In 59 per cent of the individual cases, the error arising from the statistical process,—that is, from the substitution of a mean value of $\sin i_1 \sin^2 i_2 \left(2 - \frac{r}{a}\right)$ for the true value,—will affect the deduced magnitude by less than $\pm 0^m.5$, and in 89 per cent of all cases the error will not exceed $\pm 1^m.0$. The approximation is therefore quite sufficient for our purpose. It should however be noted that, while the error of the statistical process can never make the computed absolute magnitude of any star too faint by more than $1^m.5$, it may in rare cases make it too bright by any amount whatever,—more than $2^m.0$ in one case in 60, more than $3^m.0$ once in 250 cases, and so on.

We may now proceed to compute hypothetical absolute magnitudes for all the physical pairs which show even a trace of relative motion,—including many which are ordinarily described as "fixed", but, on careful study of the observations, show very slow relative change. With the aid of the splendid collection of observational data contained in Burnham's great catalogue and other recent works on double stars, and of many observations of spectra made at Harvard in generous response to requests for information, it has been possible to derive results for more than 550 stars. Assuming that the brighter component of each of these (which is usually the only one whose spectrum is known) is equal in mass to the Sun, estimating that of the fainter component on the basis of the difference of brightness, with the data for the systems in which the mass ratio is known as a sufficient guide, and proceeding as indicated above, we obtain the data plotted in Figure 3. The coördinates have here the same meaning as in the previous diagrams, and the figure shows at a glance the relations which would exist between the absolute magnitudes and spectra of these 550 stars, if all differences of mass were eliminated, leaving only those of density and surface brightness operative. Binaries for which orbits have been computed are shown by solid dots; and physical pairs, to which the statistical process has been applied, by open circles.

Our new diagram is strikingly similar in appearance to the previous ones, even in its minor details. The two series of giant and dwarf stars appear once more; the giants are all of about the same brightness, except that those of Class B are brighter than the rest; the dwarf stars diminish in brightness by about two magnitudes for each spectral class; the two series overlap up to Class G and separate at Class K, and so on. We have clearly come, for the third time, and again from independent

data, upon the same phenomena as before; and, with the more extensive observational material, some of the characteristics and relations of the two groups are shown better than ever.

But this new evidence does much more than to confirm that which we have previously considered; it proves that the distinction between the giant and dwarf stars, and the relations between their brightness and spectral types, do not arise, (primarily at least), from differences in mass. Even when reduced to equal masses, the giant stars of Class K are about 100 times as bright as the dwarf stars of similar spectrum, and for Class M the corresponding ratio is fully 1000. Stars belonging to the two series must therefore differ greatly either in surface brightness or in density, if not in both.

There is good physical reason for believing that stars of similar spectrum and color-index are at least approximately similar in surface brightness, and that the surface brightness falls off rapidly with increasing redness. Indeed, if the stars radiate like black bodies, the relative surface brightness of any two stars should be obtainable by multiplying their relative color-index by a constant, (which is the ratio of the mean effective photographic wave-length to the difference of the mean effective visual and photographic wave-lengths, and lies usually between 3 and 4, its exact value depending upon the systems of visual and photographic magnitude adopted as standards). Such a variation of surface brightness with redness will evidently explain at least the greater part of the change in absolute magnitude among the dwarf stars, (as Hertzsprung and others have pointed out); but it makes the problem of the giant stars seem at first sight all the more puzzling.

The solution is however very simple. If a giant star of Class K, for example, is 100 times as bright as a dwarf star of the same mass and spectrum, and is equal to it in surface brightness, it must be of ten times the diameter, and $\frac{1}{1000}$ of the density of the dwarf star. If, as in Class M, the giant star is 1000 times as bright as the dwarf, it must be less than $\frac{1}{3000}$ as dense as the latter. Among the giant stars in general, the diminishing surface brightness of the redder stars must be compensated for by increasing diameter, and therefore by rapidly decreasing density, (since all the stars considered have been reduced to equal mass).

But all this rests on an assumption which, though physically very probable, cannot yet be said to be proved, and its consequences play havoc with certain generally accepted ideas. We will surely be asked,—Is the assumption of the existence of stars of such low density a reasonable or probable one? Is there any other evidence that the density of a star of Class G or K may be much less than that of the

stars of Classes B and A? Can any other evidence than that derived from the laws of radiation be produced in favor of the rapid decrease of surface brightness with increasing redness?

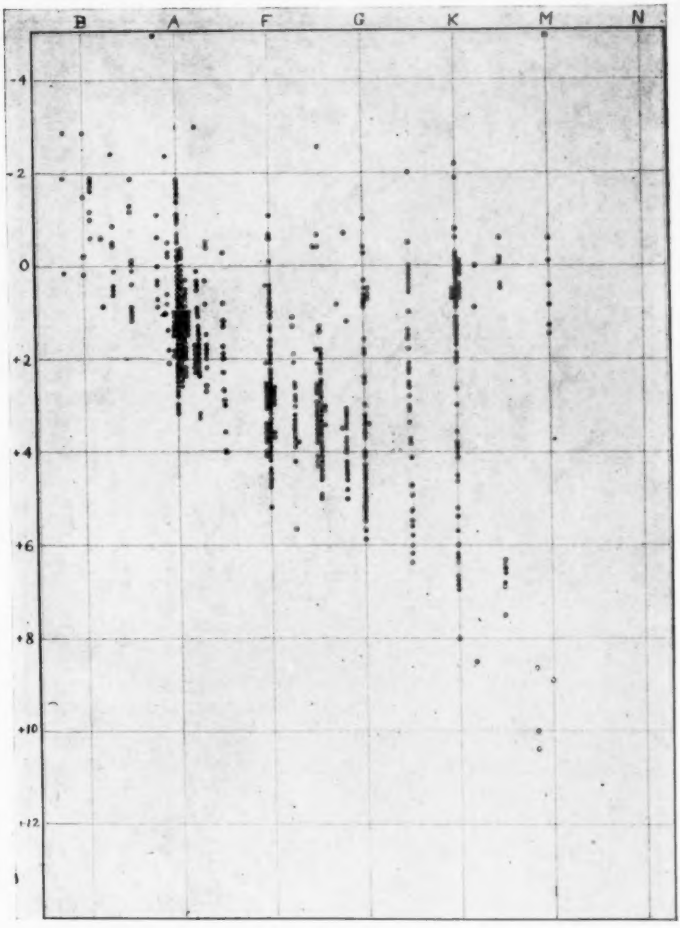

FIGURE 3.

We can give at once one piece of evidence bearing on the last question. The twelve dwarf stars of Classes K2 to M, shown in Figure 3, have, when reduced to the Sun's mass, a mean absolute magnitude of 7.8,—three magnitudes fainter than the Sun. If of the Sun's surface

brightness, they would have to be, on the average, of one fourth its radius, and their mean density would be 64 times that of the Sun, or 90 times that of water,—which is altogether incredible. A body of the

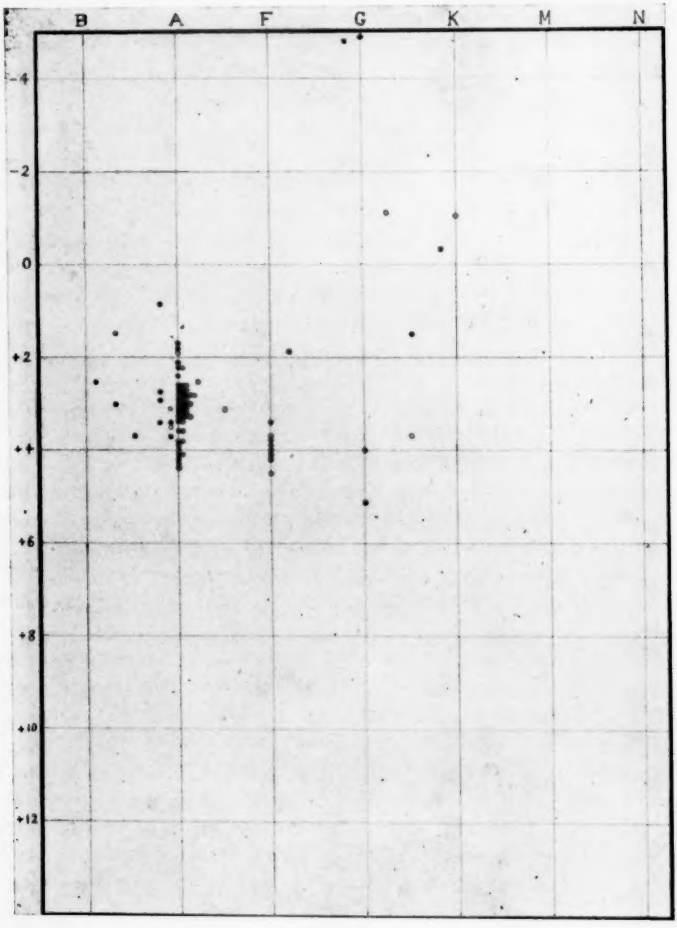

FIGURE 4.

Sun's mass and surface brightness, even if as dense as platinum, would only be two magnitudes fainter than the Sun, and the excess of faintness of these stars beyond this limit can only be reasonably ascribed to deficiency in surface brightness. For the four stars of spectra K8 and

M, whose mean absolute magnitude, reduced to the Sun's mass, is 9.5, the mean surface brightness can at most be one-tenth that of the Sun.

To proceed farther, we must have recourse to the study of eclipsing variable stars. Methods for computing their orbits have been developed at Princeton during the last few years,*—the main motive for the investigation being the astrophysical importance of the results. Dr. Shapley, using the methods devised by the speaker, has obtained elements for 87 such systems,† for each one of which the density of the components may be calculated. The values here employed are those which result from the assumption that the stars present disks darkened toward the edge, like the Sun, but to a still higher degree, and the principal uncertainty of the results, (which in any case can not be very serious), arises from our present ignorance of the actual degree of this darkening. For our present purpose, they may be best utilized by computing the absolute magnitudes which the brighter component of each system would have if its mass and surface brightness were equal to those of the Sun,—leaving outstanding the differences due to density alone.

The results for the 80 eclipsing variables whose elements and spectra are known are plotted in Figure 4, on the same system as in the preceding figures. The black dots represent those stars for which the photometric data are most reliable, the open circles those of less precision. We are once more greatly indebted to Professor Pickering and Miss Cannon for information regarding the spectra of these stars. To the absolute magnitude 4.0 on this diagram corresponds a density $\frac{1}{3}$ that of the Sun; to 3.0, $\frac{1}{11}$; to 2.0, $\frac{1}{45}$; to 1.0, $\frac{1}{180}$ of the Sun's density, and so on.

This diagram bears at first sight but small resemblance to the previous ones, but a little study brings out several important things. First; though the majority of these eclipsing variables are of Class A, every class from B to K is represented, and there are eight stars of Class G or redder. Second; all but one of these 80 stars are less dense than the Sun, though but few of them are of less than $\frac{1}{100}$ the Sun's density. Third; the stars of Classes A and B are fairly similar to one another in density, the great majority having densities between $\frac{1}{3}$ and $\frac{1}{45}$ of the Sun's; those of Class F show a compact group of high density, and an isolated star of low density; but in Classes G and K the range of density is enormously great,— from nearly twice that of the Sun (W Ursae Majoris) to one-millionth of the Sun's density (W Crucis, at the top of the diagram). Fourth; among the stars of density less than $\frac{1}{200}$ that of the Sun, (corresponding to about $+1^m.0$ on the diagram),

* Astrophys. Jour., Vol. 35, p. 315, and 36, pp. 54, 239, 385, 1912.
† Astrophys. Jour. Vol. 38, p. 159-173, 1913.

only one of the 71 stars of Classes B to F appears, while four of the eight stars of Classes G and K are included. We may now answer decisively, and in the affirmative, the first two questions which were put a few moments ago. Some stars actually have densities quite as low as any that might be required to explain the great brightness of the reddest giant stars; and these stars of low density show a very marked preference for the "later" spectral classes, while practically all the stars of "earlier" type are far denser.

We can answer the third question as well, and in a quantitative fashion, if we are willing to assume that the eclipsing binaries, and also the telescopic double stars, of the various spectral classes are typical of the stars of these classes as a whole. Though this may not be rigorously true, there is good reason to believe that it is not seriously in error. We find, from Figure 4, that the 50 eclipsing stars of Class A, if they all had the Sun's mass and surface brightness, but their own densities, would on the average be of the absolute magnitude 3.06. Now, referring to Figure 3, we find that the mean absolute magnitude which the 115 visual double stars of Class A0 there recorded would have, if they were equal in mass only to the Sun, but had their own surface brightness as well as density, would be 1.07. The only difference between these two groups, (if they are both typical of the stars of Class A in general), is that one has been reduced by computation to the Sun's surface brightness, while the other has not. It is therefore evident that the stars of Class A must, on the average, for equal surfaces, be two magnitudes brighter than the Sun. Apart from the uncertainty whether the two groups compared are exactly typical, the probable error of this determination should be less than one-tenth of a magnitude.

In similar fashion, we find that the mean absolute magnitude of 52 visual pairs of spectra Oe5 to B9, reduced to the Sun's mass, is -0.4, while that of 12 eclipsing binaries of similar spectrum, reduced to the Sun's mass and surface brightness, is $+2.8$,—which makes the surface brightness of an average star of Class B greater by $3^m.2$ than that of the Sun. Again, for the stars of Class F, we get $+2.6$ for the mean reduced absolute magnitude of the 69 visual pairs, and $+3.7$ for that of the 9 eclipsing pairs,—the difference of $1^m.1$ being approximately the effect of surface brightness (somewhat more uncertain here on account of the apparently different proportion of the giant stars in the two groups).

It appears therefore that, in passing down the spectral series from B to G, the surface brightness of the stars decreases by about one magnitude from each class to the next; and we have previously found that, among the dwarf stars, the decrease in surface brightness in passing from G to M must be at least 2½ magnitudes more. All this has been shown without making any use whatever of the physical meaning of

the spectra, which have simply been used as symbols in classifying the stars into groups. The results are obviously in accordance with the view that the differences of spectral type arise from differences of temperature. Indeed, they constitute new and important evidence in its favor. How well they agree with other independent lines of evidence is shown by comparing the relative surface brightness just computed with the color-index for the various classes. Taking A as a standard, we have

Spectrum	B	A	F	G	K	M
Surface Brightness	−1.2	0.0	+0.9	+2.0	...	+4.5 (at least)
Color-Index	−0.3	0.0	+0.3	+0.7	+1.2	+1.6

The computed differences in surface brightness are in all cases about three times the color-indices, in good agreement with the theoretical ratio.

We may now estimate the density of the redder giant stars. It appears from Figure 3 that the mean absolute magnitude of the giant stars, if reduced to the Sun's mass, is 0.6 for Class G, 0.5 for Class K, and 0.0 for Classes K5 and M. The differences between these values are small, and we may well take the general mean, 0.44, as typical of the whole. This corresponds to about 50 times the Sun's luminosity. Such a giant star of Class G, if of the Sun's surface brightness, would have to be of about seven times the Sun's radius, and of $\frac{1}{350}$ of its density. If we assume, on the basis of the foregoing study of the dwarf stars, that the surface intensities of the giant stars of Classes K and M are respectively 1.5 and 3 magnitudes fainter than that of the Sun, we find that their densities must be $\frac{1}{2800}$ and $\frac{1}{25000}$ of the Sun's density. The observed densities of several eclipsing variables of Classes G and K are of just the order of magnitude here found, so that there is direct observational evidence in favor of all our conclusions, except the very low density assigned to the giant stars of Class M, (among which no eclipsing variables have yet been found, so that their densities cannot be directly determined). But there is nothing improbable about so low a density, for we know of at least one star—W Crucis—whose density is still smaller.

Before leaving these diagrams, we should notice that, by comparing the data of Figure 3 with those of Figures 1 and 2, we may obtain the average masses of the stars of the various types. Consider, for example, the stars of spectra B to B5. From Figure 3 we see that, if these stars were reduced to the Sun's mass, without changing either their surface brightness or density, their mean absolute magnitude would be −0.6. But the actual mean absolute magnitude of the stars of this spectral class is −2.0, according to Campbell, or −0.8, according to Boss. Taking the mean of these determinations, we find that these stars are

on the average, 2.1 times as bright as stars of unit mass but of the same surface brightness and density would be,—from which it follows that their average surface area must be 2.1 times that of the latter stars, and their average mass 3.0 times that of the Sun. The uncertainty whether the groups of stars which we are comparing are really exactly similar is here more serious than usual; if Campbell's stars are taken as typical, the mean mass comes out seven times that of the Sun. It should be noticed that the "average" mass here obtained corresponds approximately to the average of the logarithms of the individual masses, and hence to their geometrical mean, which will be somewhat smaller than their arithmetical mean, and that we are here dealing with the mass of the brighter component of each system only. For the twelve spectroscopic binaries of spectrum B which are available for comparison, the mean mass of the brighter components is about 9, and the geometrical mean probably about 7.5 times the Sun's mass. As the observational selection in this case undoubtedly favors the larger masses, there is no serious discrepancy between the two results.

Proceeding similarly for the stars of the other spectral classes, we obtain the results collected in Table VII. The observed absolute magnitudes of the stars in clusters have been taken in preference to those of the stars of directly measured parallax, for the reasons already stated; and for the giant stars the mean of the results of Boss and Campbell has been used, (except for Class G, for which Boss's value alone really represents them).

TABLE VII

MEAN MASSES OF BRIGHT COMPONENTS OF DOUBLE STARS

Spectrum	Observed Absolute Mag.	Abs. Mag. reduced to Sun's Mass	Resulting Average Mass
B2	−1.4	−0.6	3.0
A0	+0.5	+1.1	2.3
A5, dwarf	+1.5	+1.6	1.2
F0 "	+2.4	+2.8	1.7
F3 "	+3.3	+3.1	0.8
F8 and G0	+4.6	+4.0	0.5
G5, dwarf	+5.1	+4.2	0.3
K0 "	+6.4	+5.5	0.3
K5 and M"	+8.9	+7.7	0.2
G and G5, giant	−0.2	+0.6	3.0
K0 "	+0.2	+0.5	1.5
K5 and M "	−0.3	0.0	1.5

The general similarity in mass among the stars of such widely different characteristics is very striking. In view of the small numbers of stars in some of the groups, the differences between the individual values should not be greatly stressed, but the gradual decrease of aver-

age mass among the dwarf stars is in accordance with the results of direct measurement. The geometrical mean of the computed masses of the bright components of the eight visual binaries of spectra A to F5, whose parallaxes have been determined with tolerable accuracy, is 1.8 times the Sun's mass; for the ten similar stars of spectra F8 to K it is 0.8.

The greater mass of the stars of Class B is hardly shown by these figures; but on this matter the testimony of the spectroscopic binaries deserves much the greater weight. The important conclusion which may be drawn from Table VII is that, although the range in mean luminosity among the various groups of stars exceeds ten-thousand-fold, the range in the mean masses probably does not exceed twenty or at most thirty-fold.

We may now summarize the facts which have been brought to light as follows:—

1. The differences in brightness between the stars of different spectral classes, and between the giant and dwarf stars of the same class, do not arise, (directly at least), from differences in mass. Indeed, the mean masses of the various groups of stars are extraordinarily similar.

2. The surface brightness of the stars diminishes rapidly with increasing redness, changing by about three times the difference in color-index, or rather more than one magnitude, from each class to the next.

3. The mean density of the stars of Classes B and A is a little more than one-tenth that of the Sun. The densities of the dwarf stars increase with increasing redness from this value through that of the Sun to a limit which cannot at present be exactly defined. This increase in density, together with the diminution in surface brightness, accounts for the rapid fall in luminosity with increasing redness among these stars.

4. The mean densities of the giant stars diminish rapidly with increasing redness, from one-tenth that of the Sun for Class A to less than one twenty-thousandth that of the Sun for Class M. This counteracts the change in surface brightness, and explains the approximate equality in luminosity of all these stars.

5. The actual existence of stars of spectra G and K, whose densities are of the order here derived, is proved by several examples among the eclipsing variables,—all of which are far less dense than any one of the more numerous eclipsing stars of "early" spectral type, with the sole exception of Beta Lyrae.

These facts have evidently a decided bearing on the problem of stellar evolution, and I will ask your indulgence during the few minutes

which remain for an outline of the theory of development to which it appears to me that they must inevitably lead.

Of all the propositions, more or less debatable, which may be made regarding stellar evolution, there is probably none that would command more general acceptance than this;—that as a star grows older it contracts. Indeed, since contraction converts potential energy of gravitation into heat, which is transferred by radiation to cooler bodies, it appears from thermodynamic principles that the general trend of change must in the long run be in this direction. It is conceivable that at some particular epoch in a star's history there might be so rapid an evolution of energy, for example,—of a radio-active nature,—that it temporarily surpassed the loss by radiation, and led to an expansion against gravity; but this would be at most a passing stage in its career, and it would still be true in the long run that the order of increasing density is the order of advancing evolution.

If now we arrange the stars which we have been studying in such an order, we must begin with the giant stars of Class M, follow the series of giant stars, in the reverse order from that in which the spectra are usually placed, up to A and B, and then, with density still increasing, though at a slower rate, proceed down the series of dwarf stars, in the usual order of the spectral classes, past the Sun, to those red stars, (again of Class M), which are the faintest at present known. There can be no doubt at all that this is the order of increasing density; if it is also the order of advancing age, we are led at once back to Lockyer's hypothesis that a star is hottest near the middle of its history, and that the redder stars fall into two groups, one of rising and the other of falling temperature*. The giant stars then represent successive stages in the heating up of a body, and must be more primitive the redder they are; the dwarf stars represent successive stages in its later cooling, and the reddest of these are the farthest advanced. We have no longer two separate series to deal with, but, a single one, beginning and ending with Class M, and with Class B in the middle,—all the intervening classes being represented, in inverse order, in each half of the sequence.

The great majority of the stars visible to the naked eye, except perhaps in Class F, are giants; hence for most of these stars the order of evolution is the reverse of that now generally assumed, and the terms "early" and "late" applied to the corresponding spectral types are actually misleading.

This is a revolutionary conclusion; but, so far as I can see, we are simply shut up to it with no reasonable escape. If stars of the type

* Phil. Trans. Vol. 184, p. 688, 1902. Proc. Roy. Soc. Vol. 65, p. 186, 1899.

of Capella, Gamma Andromedae, and Antares represent later stages of development of bodies such as Delta Orionis, Alpha Virginis, and Algol, we must admit that, as they grew older and lost energy, they have expanded, in the teeth of gravitation, to many times their original diameters, and have diminished many hundred—or even thousand—fold in density. For the same reason, we cannot regard the giant stars of Class K as later stages of those of Class G, or those of Class M as later stages of either of the others, unless we are ready to admit that they have expanded against gravity in a similar fashion. We may of course take refuge in the belief that the giant stars of the various spectral classes have no genetic relations with one another,—that no one class among them represents any stage in the evolution of stars like any of the others,—but this is to deny the possibility of forming any general scheme of evolution at all.

We might be driven to some such counsel of despair if the scheme suggested by the observed facts should prove physically impossible; but, as a matter of fact, it is in conspicuous agreement with the conclusions which may be reached directly from elementary and very probable physical considerations.

There can be very little doubt that the stars, in general, are masses of gas, and that the great majority of them, at least, are at any given moment very approximately in stable internal equilibrium under the influence of their own gravitation, and very nearly in a steady state as regards the production and radiation of heat, but are slowly contracting on account of their loss of energy. Much has been written upon the behavior of such a mass of gas, by Lane, Ritter, and several later investigators,* and many of their conclusions are well established and well known. So long as the density of the gaseous mass remains so low that the ordinary "gas laws" represent its behavior with tolerable accuracy, and so long as it remains built upon the same model, (i.e., so long as the density and temperature at geometrically homologous points vary proportionally to the central density or temperature), the central temperature, (and hence that at any series of homologous points), will vary inversely as the radius. This is often called Lane's Law, If after the contraction the star is built only approximately on the same model as before, this law will be approximately, but not exactly true.

The temperature of the layers from which the bulk of the emitted radiation comes will also rise as the star contracts, but more slowly, since the increase in density will make the gas effectively opaque in a layer whose thickness is an ever-decreasing fraction of the radius. The temperature of the outer nearly transparent gases, in which the line

* An excellent summary may be found in Emden's *Gaskugeln.*

absorption takes place, will be determined almost entirely by the energy density of the flux of radiation through them from the layers below,—that is, by the "black-body" temperature corresponding to this radiation as observed at a distance.

As the gaseous mass slowly loses energy and contracts, its effective temperature will rise, its light will grow whiter, and its surface brightness increase, while corresponding modifications will occur in the line absorption in its spectrum. Meanwhile its diameter and surface will diminish, and this will at least partially counteract the influence of the increased surface brightness, and may even overbalance it. It cannot therefore be stated, without further knowledge, in which direction the whole amount of light emitted by the body will change.

This process will go on until the gas reaches such a density that the departures of its behavior from the simple laws which hold true for a perfect gas become important. Such a density will be first reached at the center of the mass. At the high temperatures with which we are dealing, the principal departure from the simple gas laws will be that the gas becomes more difficultly compressible, so that a smaller rise in temperature than that demanded by the elementary theory will suffice to preserve equilibrium after further contraction. The rise in temperature will therefore slacken, and finally cease, first at the center, and later in the outer layers. Further contraction will only be possible if accompanied by a fall of temperature, and the heat expended in warming the mass during the earlier stages will now be gradually transmitted to the surface, and liberated by radiation, along with that generated by the contraction. During this stage, the behavior of the mass will resemble roughly that of a cooling solid body, though the rate of decrease of temperature will be far slower. The diameter and surface brightness will now both diminish, and the luminosity of the mass will fall off very rapidly as its light grows redder. It will always be much less than the luminosity of the body when it reached the same temperature while growing hotter, on account of the contraction which has taken place in the interval; and this difference of luminosity will be greater the lower the temperature selected for the comparison. Sooner or later the mass must liquefy, and then solidify, (if of composition similar to the stellar atmospheres), and at the end it will be cold and dark; but these changes will not begin, except perhaps for a few minor constituents of very high boiling point, until the surface temperature has fallen far below that of the stars of Class M, (about 3000° C).

The "critical density" at which the rise of temperature will cease can only be roughly estimated. It must certainly be much greater than that of ordinary air, and, (at least for substances of moderate molecular

weight), considerably less than that of water. Lord Kelvin.* a few years ago, expressed his agreement with a statement of Professor Perry that "speculation on this basis of perfectly gaseous stuff ought to cease when the density of the gas at the center of the star approaches one-tenth of the density of ordinary water in the laboratory."

It is clear from the context that this refers rather to the beginning of sensible departures from Lane's Law than to the actual attainment of the maximum temperature, which would come later; and it seems probable, from the considerations already mentioned, that the maximum temperature of the surface would be attained at a somewhat higher density than the maximum central temperature.

The resemblance between the characteristics that might thus be theoretically anticipated in a mass of gas of stellar dimensions, during the course of its contraction, and the actual characteristics of the series of giant and dwarf stars of the various spectral classes is so close that it might fairly be described as identity. The compensating influences of variations in density and surface brightness, which keep all the giant stars nearly equal in luminosity, the rapid fall of brightness among the dwarf stars, and the ever increasing difference between the two classes, with increasing redness, are all just what might be expected. More striking still is the entire agreement between the actual densities of the stars of the various sorts and those estimated for bodies in the different stages of development, on the basis of the general properties of gaseous matter, The densities found observationally for the giant stars of Classes G to M are such that Lane's Law must apply to them and they must grow hotter if they contract; that of the Sun, (a typical dwarf star), is so high that the reverse must almost certainly be true; and the mean density of the stars of Classes B and A (about one-ninth that of the Sun, or one-sixth that of water) is just of the order of magnitude at which a contracting mass of gas might be expected to reach its highest surface temperature.

We may carry our reasoning farther. Another deduction from the elementary theory (as easily proved as Lane's Law, but less generally known) is that, in two masses of perfect gas, similarly constituted, and of equal radius, the temperatures at homologous points are directly proportional to their masses. As in the previous case, the effective surface temperature of the more massive body will be the greater, though to a less degree than the central temperature. A large mass of gas will therefore arrive at a higher maximum temperature, upon reaching its critical density, than a small one. The highest temperatures will be attained only by the most massive bodies, and, all through their career,

* Nature, Vol. 75, p. 368, 1907.

these will reach any given temperature at a lower density, on the ascent, and return to it at a higher density, on the descending scale, than a less massive body. They will therefore be of much greater luminosity, for the same temperature, than bodies of small mass, if both are rising toward their maximum temperatures. On the descending side, the difference will be less conspicuous. Bodies of very small mass will reach only a low temperature at maximum, which may not be sufficient to enable them to shine at all.

All this again is in excellent agreement with the observed facts. The hottest stars,—those of Class B,—are, on the average, decidedly more massive than those of any other spectral type. On the present theory, this is no mere chance, but the large masses are the necessary condition,—one might almost say the cause,—of the attainment of unusually high temperature. Only these stars would pass through the whole series of the spectral classes, from M to B and back again, in the course of their evolution. Less massive bodies would not reach a higher temperature than that corresponding to a spectrum of Class A; those still less massive would not get above Class F, and so on. This steady addition of stars of smaller and smaller mass, as we proceed down the spectral series, would lower the average mass of all the stars of a given spectral class with "advancing" type, in the case of the giants as well as that of the dwarfs. This change is conspicuously shown among the dwarf stars in Table VII, and faintly indicated among the giant stars. The average masses of the giant and dwarf stars appear however to be conspicuously different, which at first sight seems inconsistent with the theory that they represent different stages in the evolution of the same masses. But the giant stars which appear in these lists have been picked out in a way that greatly favors those of high luminosity, and hence, as we have seen, those of large mass, while this is not the case among the dwarf stars. The observed differences between them are therefore in agreement with our theory, and form an additional confirmation of it.

It is now easy too to understand why there is no evidence of the existence of luminous stars of mass less than one-tenth that of the Sun. Smaller bodies presumably do not rise, even at maximum, to a temperature high enough to enable them to shine perceptibly (from the stellar standpoint) and hence we do not see them. The fact that Jupiter and Saturn are dark, though of a density comparable with that of many of the dwarf stars, confirms this view.*

* In the foregoing presentation of the theory, to avoid interference with the progress of the main argument, no mention has been made of certain considerations which should be discussed here.

1. It is probable that at stellar temperatures the gaseous matter is very con-

We may once more follow the lead of our hypothesis, into a region which, so far as I know, has been previously practically untrodden by theory. It is well known that the great majority of the stars in any given region of space are fainter than the Sun, and that there is a steady and rapid decrease in the number of stars per unit volume, with increasing luminosity. The dwarf stars, especially the fainter and redder ones, really greatly outnumber the giants, whose preponderance in our catalogues arises entirely from the egregious preference given them by the inevitable method of selection by apparent brightness.

What should we expect to find theoretically? To get an answer, we must make one reasonable assumption,—namely, that the number of stars, in any sufficiently large region of space, which are, at the present time, in any given stage of evolution will be (roughly at least) proportional to the lengths of time which it takes a star to pass through the respective stages.* While a star is growing hotter, it is large and bright, is radiating energy rapidly, and is also storing up heat in its interior; while, on account of its low density, contraction by a given percentage of its radius liberates a relatively small amount of gravitational energy. It will therefore pass through these stages with relative rapidity. Its

siderably dissociated and ionized. But this will not affect its gaseous nature. For our present purpose it amounts to little more than a diminution of the mean molecular weight. This will lower the temperature corresponding to a given density and pressure, and so tend to lower the maximum attainable temperature; but as the degree of dissociation is likely to vary gradually with the temperature, it should not affect the orderly sequence of changes which form the basis of the previous arguments.

2. It is also probable that the available potential energy of a star is not entirely gravitational, but partly, if not mainly, of radio-active or similar atomic origin. If, as in the relatively very small range accessible to experimental investigation, the rate of liberation of this energy is independent of the temperature and pressure, it would simply supply a constant annual addition to the energy derived from gravitational contraction, and the only difference in the course of events would be that a star, on cooling, would approach, not complete extinction, but a steady state, of very long duration, in which as much energy was annually radiated away as was supplied by atomic disintegration. If the rate of disintegration is increased under the extremely violent molecular collisions which must occur in the interior of a star, a great liberation of energy may occur when the interior has got hot enough, thus increasing the maximum temperature and prolonging its duration. But, even on this hypothesis, the number of the violent collisions which liberate the atomic energy would increase gradually as the temperature of the interior rose, and the general character of the evolutionary changes, including the relation of the mass and density of the body to the time of their occurrence, would not be radically altered.

It seems therefore probable that the previous reasoning would require no essential modification on account of either of these factors in the problem.

* Hertzsprung, Zeitschrift für Wissenschaftliche Photographie, Vol. 3, p. 442, 1905.

passage through its maximum temperature will obviously be somewhat slower. During the cooling stages, its surface is relatively small, and its rate of radiation slow; it is dense, and a given percentage of contraction liberates a large amount of energy; and the great store of heat earlier accumulated in its interior is coming out again. It must therefore remain in these stages for very much longer intervals of time,—especially in the later ones, when the rate of radiation is very small.

This reproduces, in its general outlines, just what is observed,—the relative rarity of giant stars, the somewhat greater abundance of those of Class A, near the maximum of temperature, and the rapidly increasing numbers of dwarf stars of smaller and smaller brightness. The well-known scarcity of stars of Class B, per unit of volume, is further accounted for if we believe, as has been already explained, that only the most massive stars reach this stage.

In this connection we will very probably be asked, What precedes or follows Class M in the proposed evolutionary series, and why do we not see stars in still earlier or later stages? With regard to the latter, it is obvious that dwarf stars still fainter than the faintest so far observed (which are of Class M) would, even if among our very nearest neighbors, be apparently fainter than the tenth magnitude. We cannot hope to find such stars until a systematic search has been made for very large proper-motions among very faint stars. The extreme redness of such stars would unfortunately render such a search by photographic methods less productive than in most cases.

But a giant star of Class M, a hundred times as bright as the Sun, certainly cannot spring into existence out of darkness. In its earlier stages it must have radiated a large amount of energy, though perhaps less than at present. But, as the temperature of a radiating body falls below 3000° C, the energy maximum in its spectrum moves far into the infra-red, leaving but a beggarly fraction of the whole radiation in the visible region. Stars in such stages, would therefore emit much less light than they would do later, and stand a poor chance of being seen.* We know as yet very little about the color-index and temperature of stars of those varieties of Class M (Mb and Mc) which are evidently furthest along in the spectral series, and it may well be that a star usually reaches the temperature corresponding to these stages by the time that it begins to shine at all brightly. In any case, stars in these very early stages should be of small or moderate luminosity, and rare per unit of volume, and hence very few of them would be included in our catalogues.

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* Russell, Science, N.S. Vol. 37, p. 646, 1913.

The great luminosity and extreme redness of the stars of Class N suggest that they belong at the beginning of the series of giant stars; but the relations of this very distinct spectral type to the others are not yet quite clear, and it would be premature to give it a definitive place in the sequence. It seems clear, however, that these stars must be in a very primitive condition, rather than in a very late one, as believed by Lockyer. The stars of Class O (Wolf-Rayet stars) are of very great average luminosity, and probably lie beyond those of Class B at the apex of the temperature scale, as Lockyer supposes. But in the absence of data concerning their masses, densities, and the like, we cannot place them definitively, except that Oe5 and Oe come almost certainly just above B0.

One further application of the theory may be very briefly mentioned. If we have a large number of contracting masses of gas, endowed with various moments of momentum, more and more of them will split up into pairs as they grow denser, and the pairs latest formed will have the shortest periods. A large percentage of spectroscopic binaries, especially of short period, is therefore direct evidence of a fairly advanced state of evolution, and the occurrence of this condition among the stars of Classes B and A supports,—indeed, almost by itself compels,—the view that they are far removed from a primitive condition. Most of the stars which have been investigated for radial velocity are giants, and the absence of spectroscopic binaries of short period among the redder ones is in agreement with the view that they are in earlier stages of evolution.

The distribution of the visual binaries and physical pairs among the various spectral classes depends mainly upon a quite different factor, namely, the resolving power of our telescopes, which allows us to separate the closer pairs of short period only among the nearer stars, so that the systems for which orbits have been determined are nearly all dwarf stars.

I have endeavored in the past hour to set before you the present state of knowledge concerning the real brightness, masses, densities, temperatures and surface brightness of the stars, and to sketch the theory of stellar evolution to which the study of these things has led me. This theory is inconsistent with the generally accepted view. Its fundamental principle is identical with that of Lockyer's classification, but it differs radically from the latter in the principles according to which it assigns individual stars, and even whole classes of stars, to the series of ascending or descending temperature. [For example, Lockyer puts such conspicuously giant stars as Canopus, Capella, Arcturus, and Beta Cygni, and all the stars of Class N, into the descend-

ing series, and places β Hydri and δ Pavonis (which are clearly dwarf stars) in the ascending series.]

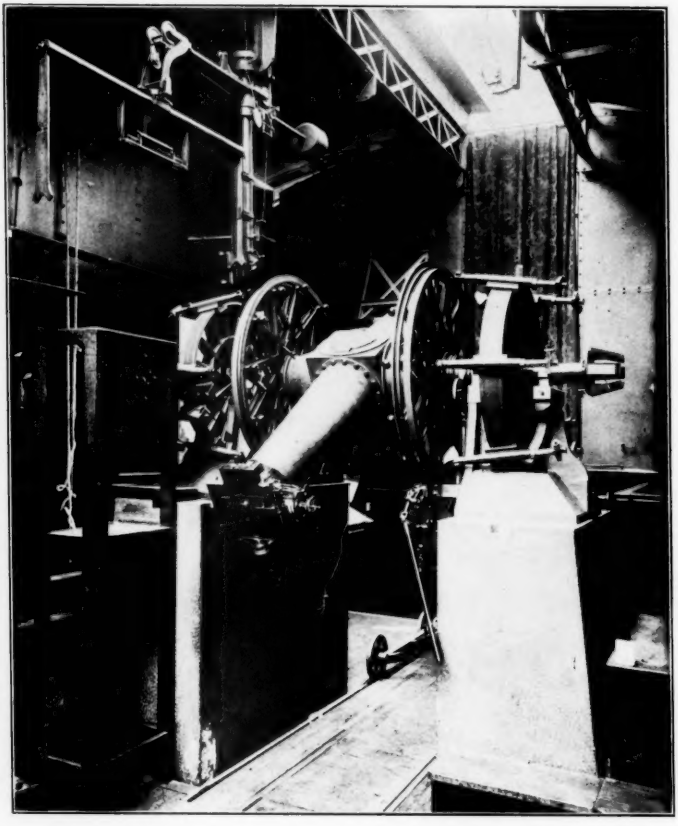
Two things have gone farthest to convince me that it may be a good approximation to the truth; the way in which it explains and coördinates characteristics of the different spectral types which previously appeared to be without connection or reason, and the way in which a number of apparent exceptions to its indications have disappeared, one by one, as more accurate information concerning spectra, orbits of double stars, and the like, became available, till only one doubtful case remains.

I have purposely made no attempt at this time to touch upon certain other interesting matters, such as the difference of the mean peculiar velocities of stars of the various spectral classes, although, with the aid of simple and very reasonable assumptions, they may be added to the list of things explainable by the new theory. My reason for this has been less for lack of time than because there is at present no definite reason, assignable from general considerations in advance, why we should expect an old star to be moving faster or slower than a younger one, while there is such a reason why we should suppose that a dense star is in a later stage of evolution than one of low density. It seems better to find out what we can about the order of evolution from data of the latter kind, and then apply our results to the study of problems of the former sort, than to attack them without such aid, or by means of unproved assumptions. The assumptions that are necessary on the new theory are simple and probable enough; but they do not form an integral part of the theory, and cannot be established directly from general considerations, and so I will not discuss them now.

The new theory will not explain everything about the stars—I would be rather afraid of it if it did;—for example, it leaves the phenomena of preferential motion, or "star-streaming" as puzzling as ever. I have only tried to interpret some of the facts most obviously capable of evolutionary explanation, on the fundamental assumption that the properties of matter, and the forces in operation, among the stars, are the same as those with which we are familiar in the laboratory. He would be a bold man indeed who would assert that this assumption is entirely true; but it seems clear that it should be thoroughly tried out before the existence of new forces can legitimately be postulated.

If the ideas to which you have so kindly listened to-day shall prove of any help toward removing the need for belief in unknown forces, and extending the domain of those already known, my labor will be far more than repaid; but it should not be forgotten that the real laborers have been those who, through long and weary nights, accumulated bit by bit, and, through monotonous days, prepared for the use of

PLATE XVI



THE BISCHOFFSHEIM MERIDIAN CIRCLE AT THE PARIS OBSERVATORY.

others, the treasures of observational knowledge with which it has been my pleasurable lot to play in the comfort of my study.

I need hardly add that, if what I have said proves of interest to any of you, your frank and unsparing criticism will be the greatest service which you can render me.

Princeton University Observatory.
1914 March 31.

REGISTERING INSTRUMENTS EMPLOYED IN THE MERIDIAN SERVICE AT THE OBSERVATORY OF PARIS.*

PROFESSOR W. SIMONIN.†

If I venture to appear before you, and to speak in your language, it is because your courteous Captain has so kindly invited me. I desire, besides, to express my appreciation of your hearty welcome, and I may perhaps be able to do so, in slight measure, by telling you something of our work at the Paris Observatory. I could wish of course, to show you our installation; for some of you I hope soon to perform this service, and I trust that in time I may be thus favored for all of you. Remember that the distance from Washington to Paris is small indeed, measured in astronomical units.

I shall confine my talk to our meridian work. Though with differing details, which it may be useful to compare at another time, the Paris Observatory, as well as your own, has replaced by a new process the old eye and ear method which beginners should always practice for a time. Even the late method of recording upon a chronograph the times of transit of stars behind the fixed threads of a reticule we have recently also discarded. The idea now is to keep the moving star bisected by a movable thread for twenty seconds or more. This the observer may do by turning the right ascension screw by hand, or he may effect it mechanically.

Two somewhat different sets of apparatus are now in use. The more recent made by M. Bonty, was tried last summer; the older, to which I shall chiefly confine my remarks, was installed in the Bischoffsheim circle house by the late P. Gautier, member of the Bureau of Longitudes. Gautier solves the problem by aid of an electric motor of which the

* An address delivered before the members of the U. S. Naval Observatory Staff, December 11, 1913.

† Astronomer at the Observatory of Paris.

observer corrects the variations only. Two vertical circles, with centres at A and B (see Fig. 1), are turned in opposite directions by the motor. An axis CD, equidistant from A and B, bears a horizontal circle EF which, at the will of the observer, may be placed in contact with, or disconnected from, the circles A and B. When EF rubs against these circles, it has imparted to it a rotary motion. The farther removed EF is from C, the faster it is made to turn, and consequently the greater is the resulting motion of the movable thread. The distance may be adjusted, for any star of polar distance greater than ten degrees, so that the movable thread will just accompany the star. For stars between ten degrees and the pole the right ascension screw is turned by hand. CD is graduated from 0 to almost 40, and it is very easy to determine by measurement the declination corresponding to each graduation.

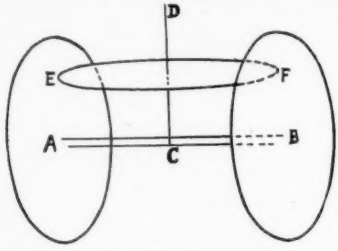


FIG. 1.

Between the motor and the axis of the screw are many wheel works needless to describe, and the mechanical details are rather complex. It is better to see the instrument itself, or a similar instrument. All of you saw, or may see, two slightly different contrivances in the longitude houses,* for the Naval Observatory ordered of M. Prin, successor to Gautier, two instruments like ours, but somewhat altered and improved in accordance with changes suggested by the last longitude determination.

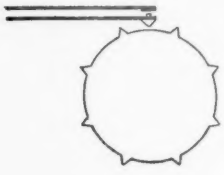


FIG. 2.

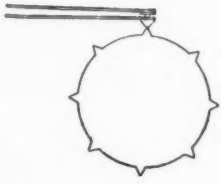


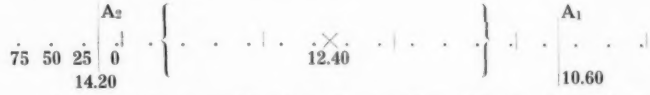
FIG. 3

For the observations to be recorded independently of the observer, the axis of the right ascension screw is provided with a circle in which are inserted, at equidistant intervals, sharp contact pieces (Figs. 2 and 3),

* The two houses at the Naval Observatory containing the instruments employed for the determination of the longitude difference between Washington and Paris.

four or eight, as the observer wishes, in the Bischoffsheim circle, five or ten in the small longitude instruments. For simplicity, let us suppose four pieces, and a fifth as a guiding mark. The screw being turned, the five pieces come successively into contact with a thin plate, thus closing an electric circuit, and causing the observation to be recorded on the chronograph. We always have more observations to each star than are necessary, but it is often well to disregard the first contacts, and it is sometimes convenient when the records are bad or the sky cloudy, to make use of supplementary observations.

In further explanation, let us assume at first that the movable thread is made to follow the star between that portion of the field enclosed by the two fixed threads of the reticule A_1 and A_2. Of the observations recorded we choose those desired in the following way. Each revolution of the screw is divided into 100 parts, and corresponds to four seconds for an equatorial star. Suppose the readings are 0, 25, 50, 75 when the electric circuit is closed by the four contacts, and 90 when this is performed by the guiding mark. The field between A_1 and A_2 may then be represented by the following sketch.



Assuming that the movable thread coincides with A_1 when the head reads $10^r.60$, and with A_2 when the reading is $14^r.20$, the half-way point is represented by the mean, or $12^r.40$. We take only five records to the right of this mean reading and five to the left, instead of the usual twenty. On the chronographic sheet we read the minute, the second and the hundredth of the second for the first, fifth, sixth and last records, and the hundredths only for the remainder. If the observation is good, the sums of the symmetrical observations are nearly the same.

In the case supposed, we omit the first of two very close records; but if the star moved in the contrary direction, from A_2 to A_1, we should omit the second. If, through some oversight, we have read four records too soon or too late, we have only to increase or diminish the result by the proper factor multiplied by 4 sec δ.

When both the right ascension and the declination are desired, it is customary to observe the right ascension before A_1 and after A_2; for we may just as well measure the first part of the transit three or four revolutions too soon, for example, provided we observe the second part three or four revolutions too late; but not much more than this. At large distances from the optic axis, in fact, the right ascension screw does not follow the motor purposely so as not to block up the screw.

The numbers 0, 25, 50, 75 above given correspond to the reverse position of the instrument, and to a forward motion of the screw. For the direct position we must unscrew, and the corresponding numbers are nearly 2, 27, 53 and 77. For small longitude instruments we take the mean. For the Bischoffsheim circle we do not; we use two different collimations corresponding to the two positions of the circle, and we allow for lateral flexure, not supposing a variable collimation, but correcting the level as determined by observations of the nadir.

Readings of Specimen Chronograph Record	Corresponding Readings of R. A. Screw	
	57.03	Fixed wire A_1
44^m 50.30	57.25	
51.24	57.50	
52.22	.75	
(52.93)	57.90	Guiding mark
53.20	58.00	
54.14	.25	
55.14	.50	
56.07	.75	
(56.80)	58.90	Guiding mark
57.08	59.00	
58.03	.25	
59.00	.50	
59.99	.75	
(0.71)	59.90	Guiding mark
0.94	60.00	
1.93	.25	
2.87	.50	
3.85	.75	
(4.55)	60.90	Guiding mark
4.80	61.00	
5.78	.25	
6.76	.50	
7.70	.75	
(8.42)	61.90	Guiding mark
8.68	62.00	
9.64	62.25	
10.62	.50	
11.60	.75	
(12.31)	62.90	Guiding mark
45^m 12.54	63.00	
.....	63.03	Fixed wire A_2

Arrangement of the Calculation for the Record of Observations

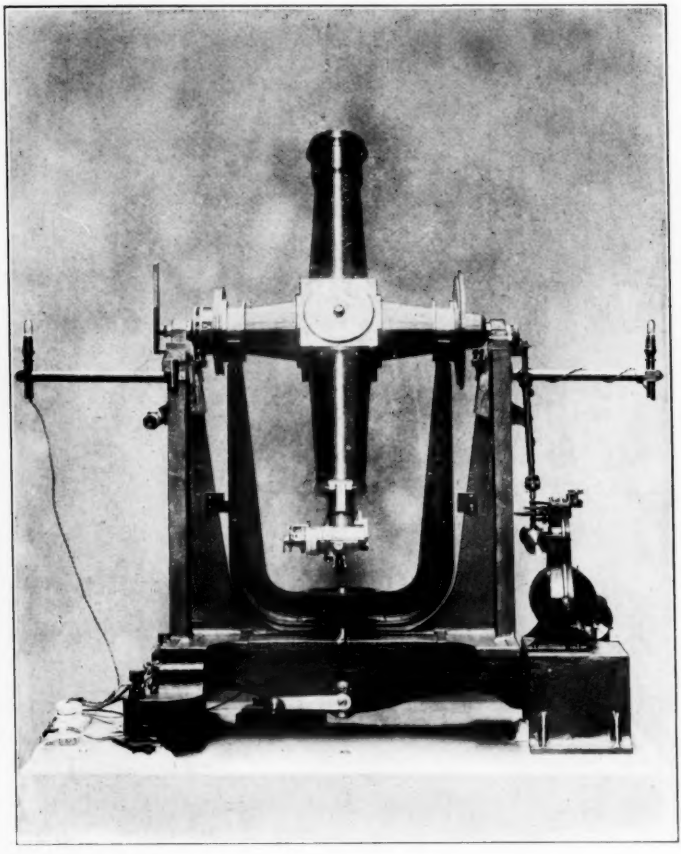
m	s	m	s	m	s
44	51.24	45	9.64	45	0.88
	.22		.68		.90
	.20		.70		.90
	.14		.76		.90
	.14		.78		.92
	.07		.80		.87
	.08		.85		.93
	.03		.87		.90
	.00		.93		.93
	59.99		0.94		0.93
				Sum	9.06
				Mean 45^m	$0^s.453$

Mean of readings on A_1 and A_2 $60^r.03$
First 10 points, from $57^r.50$ to $59^r.75$
Second 10 points, from $60^r.00$ to $62^r.25$

$$\text{Mean} \quad \frac{58.625+61.125}{2} = 59^r.875$$

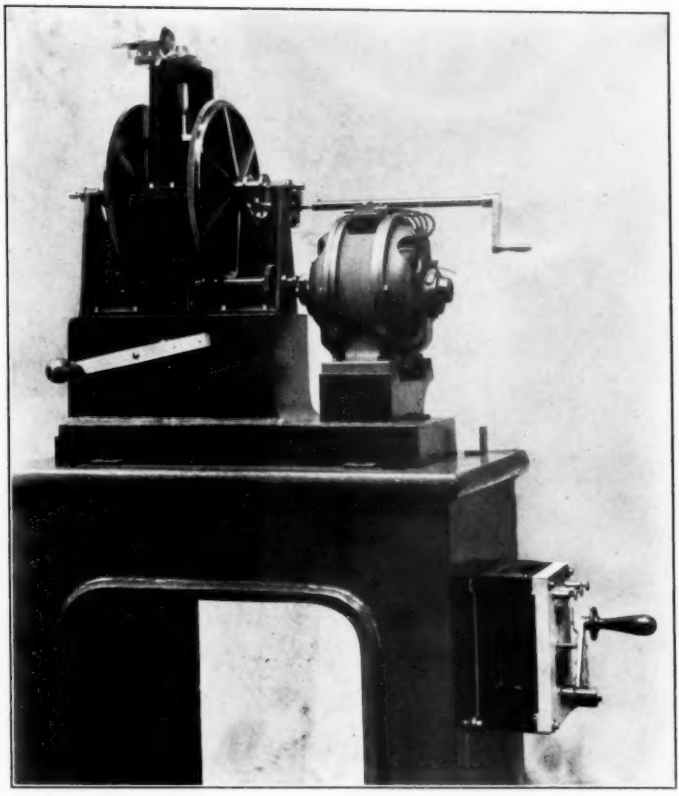
We employ the Gautier printing chronograph. The printing apparatus is composed of three wheels, on the first of which are engraved the hundredths from 0 to 99, on the others the seconds and the minutes. By means of a regulator, the first is made to revolve once in $0^s.98$ or $0^s.99$. When the chronograph needs cleaning, the wheel turns too slowly; the apparatus thus itself asks to be cleaned three or four times a year.

PLATE XVII



Prin Transit with Registering Apparatus.

PLATE XVIII



New Motor for Transit Registering Apparatus Constructed by M. Prin for the Bordeaux Observatory.

At the end of each second of a synchronized clock, the first wheel stops until the clock, sending an electric current, permits the turning of this wheel. We use different stops of the chronograph for regulating the even and the odd seconds of the clock. The first wheel leads the other two.

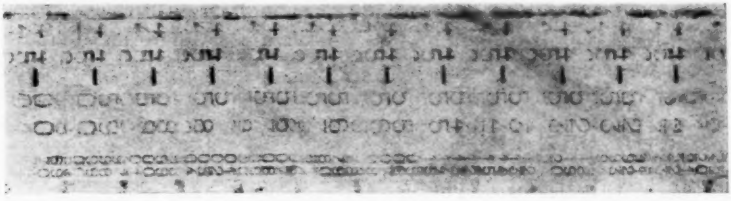


FIG. 4. Photograph of Specimen Record of the Gautier Printing Chronograph. Only about half of the record has been reproduced.

For each right ascension observation, a current goes from the instrument to the chronograph; an electro-magnet attracts a metal piece bearing three hammers; and a slip of black paper placed between the wheels and a white paper effects the printing. The two papers then advance a few millimeters.

A dash near the number corresponding to the minute indicates the correct hundredth. Some observers,—not in Paris, however,—measure by means of the dash even the third decimal. Is this really more precise?

Two years ago I found this instrument, which was new to me, very complicated, but I marvelled at the concordance of the results. Skilful observers obtained the clock correction, using but a single star, with a precision of two or three hundredths. The stars used for this purpose range from declination plus 45 degrees to minus 10 degrees; but everybody knows that even when taken from the best catalogues, either Newcomb's, adopted by both our national ephemerides, or Lewis Boss's, these stars cannot be relied upon to within several hundredths. When shall we be able to place this reliance? I wish you all to see this, and even more.

I shall now indicate the essential differences between the Gautier motor and the Bonty motor. The latter is weaker; it is fixed on the instrument, and the wheels of transmission are thus fewer. Instead of the Gautier contact pieces we have here metallic strips along the circumference of an ebonite circle. Which is the better method we do not know; but we shall compare them, and shall perhaps be led to try still a third method. I know already, however, that this second method, tried at Bruxelles, has lately been given up.

During the day we observe the sun, some of the bright stars, and only one circumpolar, α Ursae Minoris. The azimuth is thus not well known, but we prefer to determine this quantity by employing two meridian marks, connected to the meridian house by two large cylinders, thus keeping the marks always in the dark. Of course this does not add to the beauty of the surroundings; some visitors, indeed, mistake the cylinders for two water channels above ground; but I believe that, for an instrument which can not be reversed in less than ten minutes, this arrangement is a real improvement.

Before speaking of the declinations, I should like to call attention to an easy method which I found in this service for calculating the circumpolars. We sometimes have the two terms

$$k \sec \delta + ak^3 \sec^3 \delta = k \sec \delta \ (1 + ak^2 \sec^2 \delta)$$

A little table gives $\log (1 + ak^2 \sec^2 \delta)$ for tabulated values of $\log k \sec \delta$.

Instead of reading our declination measures, we record them. A wheel with sharp points on its circumference pierces a paper drawn by the wheel. The observer with one of three additional points, also pierces this paper as a record of each observation. We have, for example the arrangement of dots in Fig. 5.

FIG. 5. Specimen Record of Readings of the Declination Screw. The holes pricked in the strip of paper have been much intensified in the reproduction.

The new Bonty micrometer permits the printing of the observations at the same time with that of two even consecutive seconds, as in Fig. 6; the paper then advances a little.

FIG. 6. Specimen record from Bonty's Printing Declination Recorder.

Such are the different methods tried or employed in our meridian observations. They have been partly published in the *Bulletin Astronomique de France*.

It occurs to me that our Gautier printing chronograph, new though it is, is already old; at first one decimal only was required. I have inspected your own very interesting printing chronograph, and I await the details in your publications or the *Astronomical Journal*.

In conclusion, I wish to assure you that I shall always hold my work with you in very agreeable remembrance.

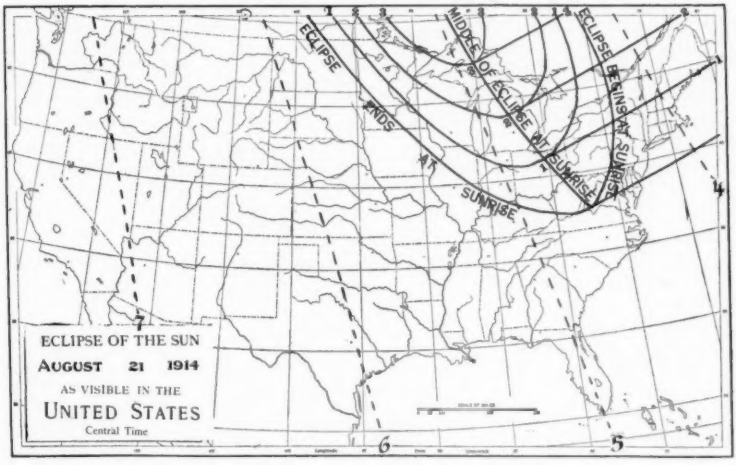
PLATE XIX

GAUTIER PRINTING CHRONOGRAPH. NEW MODEL.

THE SOLAR ECLIPSE OF 1914 AUGUST 21, AS VISIBLE IN THE UNITED STATES.

WILLIAM F. RIGGE.

The total eclipse of the sun of 1914 August 21 will be visible as a partial eclipse in the northeast section only of the United States. It will occur near the time of sunrise, and never exceed the magnitude of three tenths of the solar diameter.

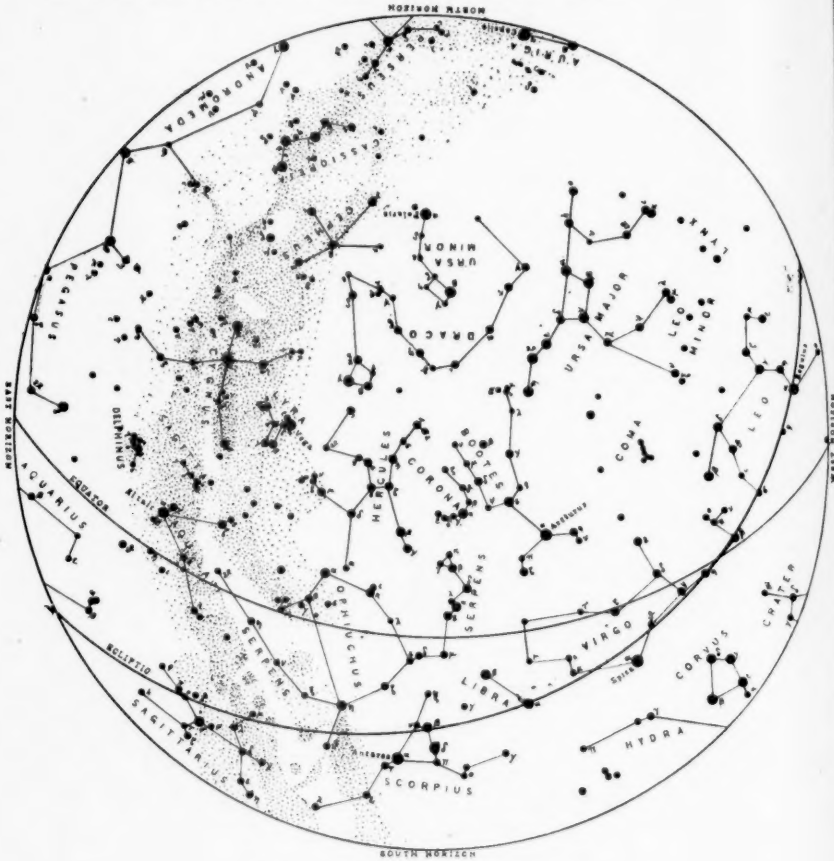


On the annexed map the meaning of the three named curves is evident from their inscriptions. The numbered curves mean the corresponding tenths of the sun's diameter obscured. The lines that are to the left of the middle of the eclipse curve, signify that the obscuration indicated occurs at the moment of sunrise and is decreasing. On those that are to the right of it, the eclipse will be increasing, and eventually reach the magnitude shown by the parallel lines that run northeastward from the middle curve. And finally the broken lines marked 4, 5, 6, 7 show the hours of sunrise in central time.

Creighton University Observatory,
Omaha, Nebr.

PLANET NOTES FOR JULY AND AUGUST, 1914.

The sun will move southward rapidly during these two months. At the beginning of July it will be more than 23 degrees north and by the end of August less than 9 degrees north. It will move eastward from Gemini through Cancer into Leo, and by the end of August will be very near the bright star Regulus.



THE CONSTELLATIONS AT 9:00 P. M. JULY 1.

Mercury will be too near the sun to be visible during the month of July. It will come to a point of inferior conjunction about the middle of the month, that is, at this time it will be between the earth and the sun. Early in August it will reach a point of greatest elongation west of the sun, and near this time it may be

seen on the eastern horizon an hour before sunrise. It immediately moves toward the sun and by the end of the month it will be back of the sun from the earth and therefore again invisible.

Venus will continue to move farther and farther east of the sun. It will set about three hours later than the sun during the latter part of August. The middle of July it will be very near Regulus and will then follow the path of the ecliptic southeast and by the end of August it will be very near Spica. It will however far exceed either of these stars in brightness.

The earth will be inaphelion, that is at its farthest point from the sun for the year. on July 2.

Mars will practically be beyond reach for observations during this period Although it will still be visible low in the west at sunset, it will be more than 200,000,000 miles away, about six times as far as it was when at its nearest position in 1912. It will be rather faint and inconspicuous because of its great distance.

Jupiter will be getting into good position again. During July it will rise shortly after sunset; on August 10 it will rise at sunset and after that before sunset. It will be quite a distance south of the equator and for that reason less favorably situated for northern observers. It will be approaching the earth during most of this period, but toward the end of August it will again recede. It will be in the constellation Aquarius but will not be near any very bright star. It will have retrograde motion throughout this period.

Saturn will again be visible as the morning star. it will be a short distance east of the Pleiades and northeast of the star Aldebaran.

Uranus will be in opposition on August 2. It will therefore rise near the time of sunset during this period. It will be in the same part of the sky as the planet Jupiter. It can be seen only with the aid of the telescope.

Neptune will be in conjunction with the sun on July 20, and will therefore be too near the sun to be visible during these two months.

Phenomena of Jupiter's Satellites.

[Visible at Washington.]

CENTRAL STANDARD TIME

1914	h	m		1914	h	m	
July 1	14	22	I Ec. Dis.	July 11	12	43	II Sh. In.
2	11	30	I Sh. In.		14	10	II Tr. In.
	12	24	I Tr. In.	13	11	18	II Oc. Re.
	13	50	I Sh. Eg.	16	12	12	IV Ec. Dis.
	14	44	I Tr. Eg.		15	18	I Sh. In.
	15	13	II Ec. Dis.	17	12	39	I Ec. Dis.
3	12	1	I Oc. Re.		13	17	III Oc. Re.
4	10	6	II Sh. In.	18	9	46	I Sh. In.
	11	50	II Tr. In.		10	20	I Tr. In.
	13	2	II Sh. Eg.		12	7	I Sh. Eg.
	14	47	II Tr. Eg.		12	40	I Tr. Eg.
6	9	1	II Oc. Re.	19	9	58	I Oc. Re.
	13	1	III Sh. In.	20	9	40	II Ec. Dis.
8	11	4	IV Tr. In.		13	34	II Oc. Re.
9	13	24	I Sh. In.	22	7	34	II Sh. Eg.
	14	9	I Tr. In.		8	32	II Tr. Eg.
10	9	55	III Oc. Re.	24	11	17	III Ec. Dis.
	10	44	I Ec. Dis.		14	33	I Ec. Dis.
	13	47	I Oc. Re.	25	11	40	I Sh. In.
11	10	13	I Sh. Eg.		12	4	I Tr. In.
	10	56	I Tr. Eg.		14	1	I Sh. Eg.

1914	h	m		1914	h	m	
July 25	14	24	I Tr. Eg.	July 27	12	15	II Ec. Dis.
26	9	2	I Ec. Dis.	29	7	15	II Sh. In.
	11	42	I Oc. Re.		7	51	II Tr. In.
27	8	29	I Sh. Eg.		10	11	II Sh. Eg.
	8	40	I Tr. Eg.		10	48	II Tr. Eg.
				31	15	17	III Ec. Dis.
Aug. 1	13	34	I Sh. In.	Aug. 14	9	34	II Ec. Re.
	13	48	I Tr. In.	16	14	34	I Oc. Dis.
2	10	57	I Ec. Dis.	17	11	41	I Tr. In.
	13	0	IV Oc. Re.		11	52	I Sh. In.
	13	26	I Oc. Re.		14	1	I Tr. Eg.
3	8	3	I Sh. In.		14	13	I Sh. Eg.
	8	14	I Tr. In.	18	9	0	I Oc. Dis.
	10	24	I Sh. Eg.		11	30	I Ec. Re.
	10	34	I Tr. Eg.		12	10	III Tr. In.
4	7	52	I Oc. Re.	9	13	3	III Sh. In.
	8	45	III Sh. Eg.	1	8	27	I Tr. Eg.
	9	21	III Tr. Eg.		8	41	I Sh. Eg.
5	9	52	II Sh. In.	21	8	41	II Oc. Dis.
	10	6	II Tr. In.		12	10	II Ec. Re.
	12	48	II Sh. Eg.	22	0	28	III Ec. Re.
	13	2	II Tr. Eg.	23	6	40	II Tr. Eg.
7	7	10	II Oc. Re.		7	20	II Sh. Eg.
8	15	29	I Sh. In.	24	13	25	I Tr. In.
	15	31	I Tr. In.		13	47	I Sh. In.
9	12	50	I Oc. Dis.	25	10	44	I Oc. Dis.
	15	10	I Oc. Re.		13	26	I Ec. Re.
10	9	57	I Tr. In.	26	7	51	I Tr. In.
	9	58	I Sh. In.		8	16	I Sh. In.
	12	17	I Tr. Eg.		10	11	I Tr. Eg.
	12	18	I Sh. Eg.		10	36	I Sh. Eg.
11	7	16	I Oc. Dis.	27	7	54	I Ec. Re.
	8	55	III Tr. In.		10	10	IV Sh. In.
	9	3	III Sh. In.		10	55	IV Tr. Eg.
	9	36	I Oc. Re.	28	10	57	II Oc. Dis.
11	12	37	III Tr. Eg.	29	10	54	III Ec. Re.
	12	45	III Sh. Eg.	30	6	0	II Tr. In.
12	6	43	I Tr. Eg.		7	1	II Sh. In.
	6	47	I Sh. Eg.		8	56	II Tr. Eg.
	12	21	II Tr. In.		9	57	II Sh. Eg.
	12	28	II Sh. In.				

Note:—In., denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh.. transit of the shadow.

Occultations Visible at Washington.

Date 1914		Star's Name	Magnitude	IMMERSION. Washington M.T. h	m	Angle f'm N. °	EMERSION. Washington M.T. h	m	Angle f'm N. °	Duration h	m
July	4	τ Scorpii	2.9	9	53	125	11	7	255	1	14
	8	17 Capricorni	5.8	12	1	67	13	24	240	1	24
	15	20 H^1 Arietis	6.4	15	16	38	16	29	251	1	13
	17	16 Tauri	5.4	13	34	85	14	29	231	0	54
	17	17 Tauri	3.8	13	48	142	14	4	173	0	15
	17	q Tauri	4.3	13	51	54	14	47	261	0	56
	17	20 Tauri	4.1	14	2	87	14	58	227	0	55
	17	21 Tauri	5.8	14	12	49	15	9	265	0	57
	17	22 Tauri	6.5	14	13	57	15	12	256	0	59
	19	107 B. Aurigae	6.5	14	8	76	14	59	265	0	51
	25	37 Sextantis	6.3	7	22	164	8	5	260	0	43
Aug.	4	36 B. Capricorni	6.2	14	41	46	15	45	255	1	4
	7	λ Aquarii	3.8	10	57	62	12	17	224	1	20
	7	78 Aquarii	6.3	12	35	61	13	57	217	1	21
	30	τ Sagittarii	3.5	9	5	90	10	22	232	1	17

VARIABLE STARS.

Approximate Magnitudes of Variable Stars of Long Period on May 1, 1914.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.	Name.	R.A. 1900 h m	Decl. 1900 ° ′	Magn.
X Androm.	0 10.8	+46 27	9.3	U Cancri	8 30.0	+19 14	12.3*d*
T Cassiop.	17.8	+55 14	10.0 *i*	S Hydrae	48.4	+ 3 27	12.0
Y Cephei	31.3	+79 48	12.6	T Hydrae	50.8	− 8 46	8.4 *i*
U Cassiop.	40.8	+47 43	8.2	T Cancri	51.0	+20 14	8.2
RV Cassiop.	47.1	+46 53	<14.0	W Cancri	9 4.0	+25 39	8.4
W Cassiop.	49.0	+58 1	8.8	X Hydrae	30.7	−14 15	11.1
U Androm.	1 9.8	+40 11	<12.0	Y Draconis	31.1	+78 18	<14.0
– Androm.	10.4	+41 12	<12.0	R Leo. Min.	39.6	+34 58	10.6*d*
RZ Persei	23.6	+50 20	10.2*i*	R Leonis	42.2	+11 54	8.5*d*
RU Androm.	32.8	+38 10	<12.0	Y Hydrae	46.4	−22 33	6.1
Y Androm.	33.7	+38 50	<12.0	V Leonis	54.5	+21 44	10.5
X Cassiop.	49.8	+58 46	10.8	R Urs. Maj.	10 37.6	+69 18	7.8 *i*
U Persei	53.0	+54 20	8.0	V Hydrae	46.8	−20 43	6.3
W Androm.	2 11.2	+43 50	10.9*d*	W Leonis	48.4	+14 15	<13.0
Z Cephei	12.8	+81 13	<14.0	R Com. Ber.	11 59.1	+19 20	<13.0
RR Persei	21.7	+50 49	<13.0	SU Virginis	12 0.0	+12 56	<12.0
RR Cephei	29.4	+80 42	13.0*d*	T Virginis	9.5	− 5 29	9.3
W Persei	43.2	+56 34	9.2	R Corvi	14.4	−18 42	10.9
Y Persei	3 20.9	+43 50	8.5	SS Virginis	20.1	+ 1 19	7.6
R Persei	23.7	+35 20	13.0*d*	T Can. Ven.	25.2	+32 3	11.0*d*
R Tauri	4 22.8	+ 9 56	<13.0	Y Virginis	28.7	− 3 52	10.3
W Tauri	22.2	+15 49	11.6*d*	T Urs. Maj.	31.8	+60 2	7.8 *i*
RX Tauri	32.8	+ 8 9	11.2*d*	R Virginis	33.4	+ 7 32	10.0
X Camelop.	32.6	+74 56	7.4	RS Urs. Maj.	34.4	+59 2	13.3 *i*
V Tauri	46.2	+17 22	13.2	S Urs. Maj.	39.6	+61 38	8.6*d*
R Aurigae	5 9.2	+53 28	9.2	RU Virginis	42.2	+ 4 42	11.4
W Aurigae	20.1	+36 49	12.4*d*	U Virginis	46.0	+ 6 6	12.0*d*
SU Tauri	43.2	+19 2	14.5	V Virginis	13 22.6	− 2 39	9.1
Z Tauri	46.7	+15 46	13.7	R Hydrae	24.2	−22 46	5.2*d*
U Orionis	49.9	+20 10	7.6 *i*	S Virginis	27.8	− 6 41	10.6*d*
V Camelop.	49.4	+74 30	14.0	R Can. Ven.	44.6	+40 2	7.2
Z Aurigae	53.6	+53 18	10.3	Z Bootis	14 1.7	+13 59	<13.0
X Aurigae	6 4.4	+50 15	12.0*d*	U Urs. Min.	15.1	+67 15	8.8*d*
V Aurigae	16.5	+47 45	11.4*d*	S Bootis	19.5	+54 16	9.0*d*
V Monoc.	17.7	− 2 9	8.6*d*	RS Virginis	22.3	+ 5 8	12.0 *i*
Z Monoc.	28.0	− 8 48	8.3	V Bootis	25.7	+39 18	7.7 *i*
U Lyncis	31.8	+59 57	9.8	R Camelop.	25.1	+84 17	9.4*d*
S Lyncis	35.9	+58 0	10.2 *i*	R Bootis	32.8	+27 10	12.0*d*
X Gemin.	40.7	+30 23	8.7 *i*	U Bootis	48.7	+18 6	11.3
Nova. Gem. No.2	45.5	+32 17	11.3	RT Librae	15 0.8	−18 21	<13.0
Y Monoc.	51.3	+11 22	13.2*d*	T Librae	5.0	−19 38	<12.0
X Monoc.	52.4	− 8 56	8.4	Y Librae	6.4	− 5 38	<13.0
R Lyncis	53.0	+55 28	9.0*d*	S Librae	15.6	−20 2	10.0
V Can. Min.	7 1.5	+ 9 2	14.6	S Cor. Bor.	17.3	+31 44	8.8
R Gemin.	1.3	+22 52	<12.0	RU Librae	27.7	−14 59	12.9
R Can. Min.	3.2	+10 11	10.8	S Urs. Min.	33.4	+78 58	10.5 *i*
S Can. Min.	27.3	+ 8 32	9.0*d*	V Cor. Bor.	46.0	+39 52	9.0
T Can. Min.	28.4	+11 58	12.0*d*	R Serpentis	46.1	+15 26	6.0
U Can.Min.	35.9	+ 8 37	13.2*d*	X Herculis	59.6	+47 31	6.2
S Gemin.	37.0	+23 41	13.0*d*	RU Herculis	16 6.0	+25 20	11.8*d*
T Gemin.	43.3	+23 59	8.9*d*	W Cor. Bor.	11.8	+38 3	13.1
U Puppis	56.1	−12 34	<12.0	U Herculis	21.4	+19 7	8.2
R Cancri	8 11.0	+12 2	10.0	W Herculis	31.7	+37 32	13.2
RT Hydrae	24.7	− 5 59	7.8	R Urs. Min.	31.3	+72 28	9.8

Approximate Magnitudes of Variable Stars of Long Period on May 1, 1914.—Continued.

Name.	R. A. 1900.	Decl. 1900.	Magn.	Name.	R.A. 1900.	Dec. 1900.	Magn.
	h m	° ′			h m	° ′	
R Draconis	16 32.4	+66 58	7.9*d*	R Cygni	19 34.1	+49 58	7.4
S Draconis	40.8	+55 7	8.6	TT Cygni	37.1	+32 23	8.0
RT Herculis	17 6.8	+27 11	<13.0	RT Cygni	40.8	+48 32	8.5
T Draconis	54.8	+58 14	11.1	TU Cygni	43.3	+48 49	13.6
RY Herculis	55.4	+19 29	11.0	χ Cygni	46.7	+32 40	12.0*d*
V Draconis	56.3	+54 53	9.6	SV Cygni	20 6.5	+47 35	9.0
T Herculis	18 5.3	+31 0	8.0*d*	RS Cygni	9.8	+38 28	8.2
W Draconis	5.4	+65 56	14.0	V Sagittae	15.8	+20 47	12.2
X Draconis	6.8	+66 8	11.0 *i*	U Cygni	16.5	+47 35	8.8 *i*
W Lyrae	11.5	+36 38	12.2*d*	RW Cygni	25.2	+39 39	9.2
SV Draconis	31.2	+49 18	13.3*d*	ST Cygni	29.9	+54 38	13.9
RY Lyrae	41.2	+34 34	9.0	TW Cygni	21 1.8	+29 0	13.4
R Scuti	42.2	− 5 49	5.6	X Cephei	3.6	+82 40	10.8 *i*
Z Lyrae	56.0	+34 49	13.8	T Cephei	8.2	+68 5	10.4
R Aquilae	19 1.6	+ 8 5	10.2	W Cygni	32.2	+44 56	5.2
V Lyrae	5.2	+29 30	10.0*d*	RV Cygni	39.1	+37 34	8.2
S Lyrae	9.1	+25 50	13.9	Y Pegasi	22 6.8	+13 52	<13.0
U Draconis	9.9	+67 7	10.4 *i*	RS Pegasi	7.4	+14 4	<13.0
R Sagittarii	10.8	−19 29	8.2	Z Cassiop.	23 39.7	+56 2	13.8*d*
TZ Cygni	13.4	+50 0	10.4	R Cassiop.	53.3	+50 50	11.5 *i*
U Lyrae	16.6	+37 42	9.2	Y Cassiop.	58.2	+55 7	12.0*d*
				SV Androm.	59.2	+39 33	13.0

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign < that the variable is fainter than the appended magnitude.

The above magnitudes have been compiled at the Harvard College Observatory from observations made by the following observers:—H. C. Bancroft, Jr., L. Barbour, T. C. H. Bouton, A. B. Burbeck, H. O. Eaton, E. Gray, S. C.Hunter, M. W. Jacobs, Jr., J. B. Lacchini, C. B. Lindsley, O. Mach, C. Y. McAteer, W. T. Olcott, P. G. O'Reilly, C. Richter, E. Padova, E. W. Putnam, H. M. Swartz, D. Todd, H. W. Vrooman, I. E. Woods and A. S. Young.

Maxima of Variable Stars of Short Period.

[Calculated by Julia M. Hawkes and May E. Abbott at Goodsell Observatory.]

Given to the nearest hour in Greenwich mean time. To obtain Eastern standard time subtract 5^h; Central standard time 6^h; etc.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1914 July-Aug.							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	
SX Cassiop.	0 05.5	+54 20	8.6— 9.4	36 13.7	12 10			17 23				
SY Cassiop.	0 09.8	+57 52	9.3— 9.9	4 1.7	7 0;	23 7;	8 14;	24 21				
RR Ceti	1 27.0	+ 0 50	8.3— 9.0	0 13.3	4 13;	20 1;	5 12;	21 0				
RW Cassiop.	1 30.7	+57 15	8.9—11.0	14 19.2	4 12;	19 7;	3 2;	17 22				
V Arietis	2 09.6	+11 46	8.3— 9.0	0 23.8	7 13;	23 10;	8 8;	24 5				
SU Cassiop.	2 43.0	+68 28	6.5— 7.0	1 22.8	2 1;	17 15;	2 6;	17 20				
TU Persei	3 01.8	+52 49	11.4—12.2	0 14.6	5 11;	20 1;	4 15;	18 4				
RW Camelop.	3 46.2	+58 21	8.2— 9.4	16 00.0	7 0;	23 0;	8 0;	24 0				
SX Persei	4 10.2	+41 27	10.4—11.2	4 07.0	2 15;	19 18;	5 22;	24 2				
SV Persei	42.8	+42 07	8.8— 9.6	11 03.1	9 12;	31 19;	11 22;	23 1				
RX Aurigae	4 54.5	+39 49	7.2— 8.1	11 15.0	1 6;	24 12;	5 3;	28 10				
SX Aurigae	5 04.6	+42 02	8.0— 8.7	1 12.8	5 7;	20 15;	4 22;	20 6				
SY Aurigae	05.5	+42 41	8.4— 9.5	10 03.3	2 23;	23 6;	2 9;	22 16				
Y Aurigae	21.5	+42 21	8.6— 9.6	3 20.6	7 14;	23 0;	7 11;	22 21				
RZ Gemin.	5 56.6	+22 12	9.1—10.0	5 12.7	11 8;	27 22;	13 12;	30 2				
RS Orionis	6 16.5	+14 44	8.2— 8.9	7 13.6	3 15;	18 18;	2 21;	18 0				
T Monoc.	19.8	+ 7 08	5.7— 6.8	27 00.3	16 11		12 11					
RZ Camelop.	23.7	+67 06	11.0—13.0	0 11.5	4 0;	18 10;	1 20;	23 11				

Maxima of Variable Stars of Short Period.—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1914. July-Aug.							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
W Gemin.	6 29.2	+15 24	6.7— 7.5	7 22.0	5 12;	21 8;	6 4;	22 0				
ζ Gemin.	6 58.2	+20 43	3.7— 4.3	10 03.7	3 5;	23 12;	2 16;	22 23				
RU Camelop.	7 10.9	+69 51	8.5— 9.8	22 06.5	22 23;		14 5					
RR Gemin.	7 15.2	+31 04	10.0—11.5	0 09.5	5 9;	21 6;	6 4;	22 1				
V Carinae	8 26.7	−59 47	7.4— 8.1	6 16.7	8 14;	28 17;	11 2;	31 4				
T Velorum	8 34.4	−47 01	7.6— 8.5	4 15.3	6 18;	25 7;	3 14;	22 3				
V Velorum	9 19.2	−55 32	7.5— 8.2	4 08.9	5 4;	22 16;	9 3;	26 15				
Z Leonis	9 46.4	+27 22	7.9— 9.6	59 0.0			17 0					
RR Leonis	10 02.1	+24 29	9.1—10.1	0 10.9	13 22;	27 12;	10 1;	23 15				
SU Draconis	11 32.2	+67 53	8.9— 9.6	0 15.8	10 12;	23 17;	11 13;	24 18				
S Muscae	12 07.4	−69 36	6.4— 7.3	9 15.8	7 5;	26 13;	5 4;	24 12				
SW Draconis	12.8	+70 04	8.8— 9.6	0 13.7	5 17;	21 16;	6 15;	22 13				
T Crucis	15.9	−61 44	6.8— 7.6	6 17.6	12 13;	26 1;	8 12;	21 23				
R Crucis	18.1	−61 04	6.8— 7.9	5 19.8	8 4;	25 16;	12 3;	29 14				
S Crucis	12 48.4	−57 53	6.5— 7.6	4 16.6	12 12;	26 14;	9 15;	23 17				
W Virginis	13 20.9	− 2 52	8.7—10.4	17 06.5	10 19;	28 2;	14 8;	31 14				
SS Hydrae	25.0	−23 08	7.4— 8.1	8 4.8	8 14;	25 0;	10 10;	26 19				
RV Urs. Maj.	13 29.4	+54 31	9.2— 9.9	0 11.2	11 18;	25 19;	8 20;	22 21				
ST Virginis	14 22.5	− 0 27	10.3—11.4	0 09.9	5 0;	21 10;	6 20;	23 6				
V Centauri	25.4	−56 27	6.4— 7.8	5 11.9	7 16;	24 4;	9 15;	26 3				
RS Bootis	29.3	+32 11	8.9—10.0	0 09.1	4 14;	19 16;	3 18;	18 21				
RU Bootis	14 41.5	+23 44	12.8—14.3	0 11.9	5 10;	20 6;	4 2;	18 21				
R Triang. Austr.	15 10.8	−66 08	6.7— 7.4	3 09.3	8 14;	28 22;	11 11;	31 19				
S Triang. Austr.	15 52.2	−63 29	6.4— 7.4	6 07.8	1 20;	20 20;	8 19;	27 18				
S Normae	16 10.6	−57 39	6.6— 7.6	9 18.1	1 7;	20 19;	9 8;	28 20				
RW Draconis	33.7	+58 03	9.6—10.8	0 10.6	7 19;	25 13;	12 6;	29 23				
RV Scorpii	16 51.8	−33 27	6.7— 7.4	6 01.5	4 8;	22 13;	9 17;	27 22				
X Sagittarii	17 41.3	−27 48	4.4— 5.0	7 00.3	13 21;	27 22;	10 22;	24 23				
Y Ophiuchi	47.3	− 6 07	6.1— 6.5	17 02.9	5 5;	22 8;	8 11;	25 14				
W Sagittarii	17 58.6	−29 35	4.3— 5.1	7 14.3	3 1;	18 5;	2 10;	17 14				
Y Sagittarii	18 15.5	−18 54	5.4— 6.2	5 18.6	4 23;	22 7;	8 15;	25 22				
U Sagittarii	26.0	−19 12	6.5— 7.3	6 17.9	10 3;	23 15;	6 2;	19 14				
Y Scuti	32.6	− 8 27	8.7— 9.2	10 08.3	7 13;	28 6;	7 14;	28 7				
Y Lyrae	34.2	+43 52	11.3—12.3	0 12.1	6 16;	24 19;	11 21;	29 23				
RZ Lyrae	39.9	+32 42	9.9—11.2	0 12.3	7 12;	25 22;	13 7;	31 17				
RT Scuti	44.1	−10 30	9.1— 9.7	0 11.9	8 6;	26 3;	12 23;	30 19				
κ Pavonis	18 46.6	−67 22	3.8— 5.2	9 02.2	6 16;	24 21;	12 1;	30 6				
U Aquilae	19 24.0	− 7 15	6.2— 6.9	7 00.6	12 20;	26 22;	9 23;	24 0				
XZ Cygni	30.4	+56 10	8.6— 9.3	0 11.2	8 10;	22 10;	5 10;	19 9				
U Vulpec.	32.2	+20 07	6.5— 7.6	7 23.5	6 23;	22 22;	7 21;	23 20				
SU Cygni	40.8	+29 01	6.2— 7.0	3 20.3	3 8;	18 18;	3 3;	18 12				
η Aquilae	47.4	+ 0 45	3.7— 4.5	7 04.2	10 8;	24 16;	8 1;	22 9				
S Sagittae	51.5	+16 22	5.6— 6.4	8 09.2	3 12;	20 7;	6 1;	22 20				
X Vulpec.	19 53.3	+26 17	9.5—10.5	6 07.7	12 14;	25 6;	6 21;	19 12				
X Cygni	20 39.5	+35 14	6.0— 7.0	16 09.3	2 21;	19 6;	4 15;	21 1				
T Vulpec.	47.2	+27 52	5.5— 6.1	4 10.5	11 19;	25 2;	7 9;	20 17				
WY Cygni	52.3	+30 03	9.6—10.4	0 13.5	13 18;	27 5;	9 16;	23 2				
RV Capric.	55.9	−15 37	9.2—10.1	0 10.7	14 9;	27 19;	10 5;	23 16				
TX Cygni	20 56.4	+42 12	8.5— 9.7	14 17.4	12 20;	27 13;	11 7;	26 0				
VY Cygni	21 00.4	+39 34	8.8— 9.5	7 20.6	2 7;	18 0;	2 17;	18 1				
SW Aquarii	10.2	− 0 20	9.9—10.8	0 11.0	13 2;	26 21;	9 16;	23 10				
VZ Cygni	21 47.7	+42 40	8.2— 9.2	4 20.7	11 8;	25 22;	9 12;	24 2				
Y Lacertae	22 05.2	+50 33	9.1— 9.6	4 07.8	9 11;	26 18;	13 2;	30 9				
δ Cephei	25.5	+57 54	3.7— 4.6	5 08.8	11 16;	27 18;	12 20;	28 23				
Z Lacertae	36.9	+56 18	8.2— 9.0	10 21.1	11 1;	21 22;	1 19;	23 13				
RR Lacertae	37.5	+55 55	8.5— 9.2	6 10.1	13 9;	26 5;	8 1;	20 21				
V Lacertae	22 44.5	+55 48	8.2— 8.9	4 23.6	10 1;	25 0;	8 23;	23 22				
SW Cassiop.	23 03.7	+58 11	9.2— 9.7	5 10.6	11 7;	27 14;	13 22;	30 6				
RS Cassiop.	32.6	+61 52	9.0—11.0	6 07.1	3 6;	22 3;	10 1;	28 22				
RY Cassiop.	47.2	+58 11	9.3—11.8	12 03.4	3 10;	27 17;	8 20;	21 0				
V Cephei	23 51.7	+82 38	6.0— 7.0	0 23.9	9 2;	24 2;	8 1;	23 0				

Minima of Variable Stars of Short Period.

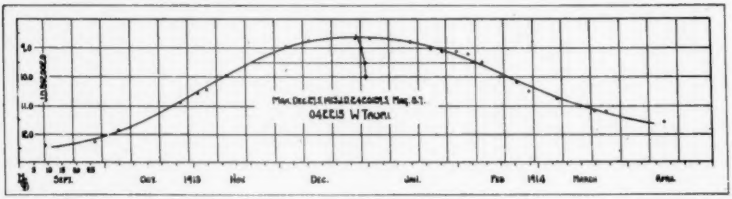
[Calculated by May E. Abbott, at Goodsell Observatory.]

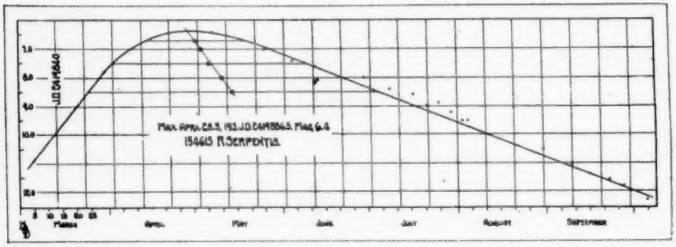
Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5h; Central Standard 6h; etc.

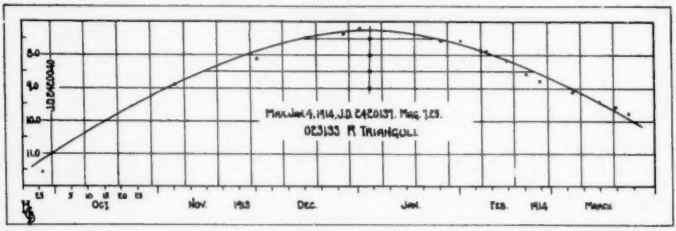
Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1914 July-Aug.							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
SY Androm.	0 08.0	+43 09	9.5—13.0	34 21.8			30 17;					
RT Sculptor.	31.5	−26 13	9.6—10.5	0 12.3	13 23;	29 8;	13 17;	29 1				
UU Androm.	38.5	+30 24	10.7—11.9	1 11.7	11 3;	26 0;	9 21;	24 17				
U Cephei	0 53.4	+81 20	7.0— 9.0	2 11.8	3 8;	18 7;	2 6;	17 5				
Z Persei	2 33.7	+41 46	9.4—12	3 01.4	11 10;	29 18;	11 0;	23 5				
TW Cassiop.	37.6	+65 19	8.2— 9.0	1 10.3	12 11;	26 17;	10 0;	24 6				
RY Persei	39.0	+47 43	8.0—10.3	6 20.7	9 20;	23 13;	6 7;	20 0				
RZ Cassiop.	39.9	+69 13	6.9— 8.1	1 04.7	5 16;	20 0;	3 8;	17 16				
TX Cassiop.	44.4	+62 22	9.4—10.1	2 22.2	3 1;	20 14;	7 4;	24 17				
ST Persei	53.7	+38 47	8.5—10.5	2 15.6	8 22;	24 19;	9 17;	25 14				
RX Cassiop.	2 58.8	+67 11	8.6— 9.1	32 07.6	8 14		9 22					
Algol	3 01.7	+40 34	2.3— 3.5	2 20.8	12 1;	23 12;	9 19;	21 6				
RT Persei	16.7	+46 12	9.5—11.5	0 20.4	8 11;	22 1;	11 10;	25 0				
λ Tauri	55.1	+12 12	3.3— 4.2	3 22.9	6 21;	22 16;	7 12;	23 7				
RW Tauri	3 57.8	+27 51	7.1—<11	2 18.5	2 4;	18 18;	4 9;	21 0				
RV Persei	4 04.2	+33 59	9.5—11.0	1 23.4	4 21;	20 15;	5 10;	21 5				
RW Persei	13.3	+42 04	8.8—11.0	15 04.8	7 16;	20 21;	3 2;	29 11				
SZ Tauri	31.4	+18 20	7.2— 7.7	3 03.6	9 12;	28 10;	6 20;	25 18				
RS Cephei	4 48.6	+80 06	9.5—12.0	12 10.1	6 0;	30 20;	12 6;	24 16				
TT Aurigae	5 02.8	+39 27	7.8—8.7	0 16.0	11 8;	24 16;	7 0;	20 8				
RY Aurigae	11.5	+38 13	10.7—11.7	2 17.5	6 15;	23 0;	8 8;	24 17				
RZ Aurigae	42.9	+31 40	10.6—13.3	3 00.3	8 11;	26 12;	13 14;	31 15				
SV Tauri	45.8	+28 05	9.4—11.0	2 04.0	7 12;	24 20;	11 4;	28 13				
Z Orionis	50.2	+13 40	9.7—10.7	5 04.9	1 7;	22 3;	1 13;	22 8				
SV Gemin.	54.6	+24 28	9.8—<11	4 00.2	7 9;	23 9;	8 10;	24 11				
RW Gemin.	5 55.4	+23 08	9.5—11.0	2 20.8	8 20;	26 1;	12 6;	29 10				
U Columbae	6 11.2	−33 03	9.2—10.0	2 19.2	1 19;	18 15;	4 10;	21 5				
SX Gemin.	22.0	+20 37	10.8—11.5	1 08.8	10 9;	26 19;	12 4;	28 14				
RW Monoc.	29.3	+ 8 54	9.0—10.8	1 21.7	4 16;	19 22;	4 4;	19 10				
RX Gemin.	43.6	+33 21	8.8— 9.6	12 05.0	12 5;	24 10;	5 15;	30 1				
RU Monoc.	6 49.4	− 7 28	9.8—10.5	0 21.5	4 6;	18 14;	9 2;	23 10				
R Can. Maj.	7 14.9	−16 12	5.8— 6.4	1 03.3	5 22;	24 2;	11 6;	29 10				
RY Gemin.	21.7	+15 52	8.9—<10	9 07.2	7 20;	26 11;	4 18;	23 8				
Y Camelop.	27.6	+76 17	9.5—12	3 07.3	8 15;	28 11;	7 9;	27 5				
TX Gemin.	30.3	+17 8	10.0—11.9	2 19.2	4 20;	21 15;	7 10;	24 5				
RR Puppis	43.5	−41 08	9.4—10.7	6 10.3	12 17;	25 14;	7 11;	20 7				
V Puppis	7 55.4	−48 58	4.1— 4.8	1 10.9	8 19;	23 8;	6 21;	21 10				
X Carinae	8 29.1	−58 53	7.9— 8.7	0 13.0	1 5;	17 11;	2 16;	18 22				
S Cancri	8 38.2	+19 24	8.2—10	9 11.6	6 18;	25 17;	4 4;	23 4				
RX Hydrae	9 0.8	− 7 52	9.1—10.5	2 6.8	2 22;	21 4;	8 10;	26 16				
S Antliae	27.9	−28 11	6.3— 6.8	0 07.8	3 12;	22 22;	11 9;	30 20				
S Velorum	29.4	−44 46	7.8— 9.3	5 22.4	5 20;	23 15;	10 11;	28 6				
Y Leonis	9 31.1	+26 41	9.3—11.2	1 16.5	8 10;	25 7;	11 3;	28 0				
RR Velorum	10 17.8	−41 36	10.0—10.9	1 20.5	1 16;	20 5;	7 18;	27 7				
SS Carinae	10 54.2	−61 23	12.2—12.8	3 07.2	12 7;	25 12;	7 17;	20 22				
ST Urs. Maj.	11 22.4	+45 44	6.7— 7.2	8 19.2	9 10;	27 0;	13 14;	31 5				
RW Urs. Maj.	35.4	−52 34	10.3—11.4	7 07.9	7 3;	21 19;	5 11;	20 3				
Z Draconis	11 39.8	+72 49	9.9—13.6	1 08.6	8 23;	22 13;	5 2;	18 16				
RZ Centauri	12 55.6	−64 05	8.5— 8.9	1 21.0	7 11;	22 11;	6 12;	21 12				
SS Centauri	13 07.2	−63 37	8.8—10.4	2 11.5	5 5;	20 2;	3 23;	18 20				
δ Librae	14 55.6	− 8 07	4.8— 6.2	2 07.9	10 20;	24 19;	7 18;	21 17				
U Coronae	15 14.1	+32 01	7.6— 8.7	3 10.9	10 11;	24 7;	7 2;	20 22				
TW Draconis	32.4	+64 14	7.3— 8.9	2 19.4	6 23;	23 19;	9 15;	26 12				
SS Librae	15 43.4	−15 14	9.3—11.5	0 18.4	6 12;	21 20;	6 3;	21 11				

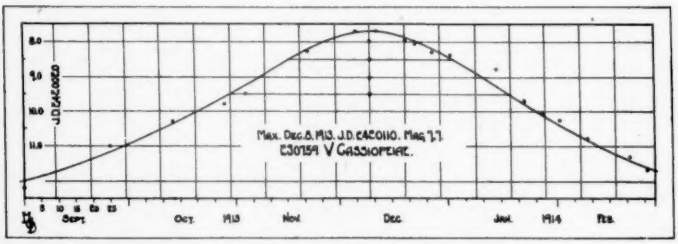
Minima of Variable Stars of Short Period.—Continued.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean time of minima in 1914 July-Aug.			
	h m	° ′		d h	d h	d h	d h	d h
SW Ophiuchi	16 11.1	— 6 44	9.2—10.0	2 10.7	7 2;	21 18;	5 10;	20 2
SX Ophiuchi	12.6	— 6 25	10.5—11.2	2 01.5	4 5;	20 17;	6 5;	22 17
R Arae	31.1	−56 48	6.8— 7.9	4 10.2	3 17;	21 10;	8 3;	25 20
TT Herculis	16 49.9	+17 00	8.9— 9.3	20 18.1	8 16;	29 12;	8 4;	28 22
TU Herculis	17 09.8	+30 50	9.5—12	2 06.4	11 11;	25 2;	7 16;	21 7
U Ophiuchi	11.5	+ 1 19	6.0— 6.7	0 20.1	3 23;	20 18;	6 12;	23 7
u Herculis	13.6	+33 12	4.6— 5.4	2 01.2	10 15;	22 23;	10 10;	22 17
TX Herculis	15.4	+42 00	8.3— 9.0	1 00.7	8 17;	23 4;	6 14;	21 0
RV Ophiuchi	29.8	+ 7 19	9. —12	3 16.5	7 10;	22 4;	5 22;	20 16
SZ Herculis	36.0	+33 01	9.5—10.3	0 19.6	5 14;	21 22;	7 7;	23 16
TX Scorpii	48.6	−34 13	7.5— 8.2	0 22.6	4 19;	19 20;	3 22;	19 0
UX Herculis	49.7	+16 57	8.8—10.5	1 13.2	5 10;	20 22;	5 10;	20 21
Z Herculis	53.6	+15 09	7.1— 7.9	3 23.8	3 6;	19 5;	4 4;	20 4
WX Sagittae	53.6	—17 24	9.2—10.8	2 03.1	8 10;	25 11;	11 12;	28 12
WY Sagittae	17 54.9	—23 1	9.5—10.6	4 16.0	7 16;	26 8;	4 16;	23 8
SX Draconis	18 03.0	+58 23	9.3—10.5	5 04.1	2 21;	23 13;	2 21;	23 13
RS Sagittarii	11.0	−34 08	5.9— 6.3	2 10.0	6 17;	21 5;	4 17;	19 5
V Serpentis	11.1	−15 34	9.5—11.1	3 10.9	14 14;	28 9;	11 5;	25 1
RZ Scuti	21.1	— 9 15	7.4— 8.3	15 03.2	6 8;	21 12;	5 15;	20 18
RZ Draconis	21.8	+ 58 50	9.5—10.2	0 13.2	4 14;	21 2;	6 15;	23 4
RX Herculis	26.0	+12 32	7.0— 7.6	0 21.3	6 5;	24 0;	10 19;	28 14
SX Sagittarii	39.7	−30 36	8.7— 9.8	2 01.8	2 2;	18 16;	4 7;	20 22
RR Draconis	40.8	+62 34	9.3—13	2 19.9	8 1;	25 1;	11 1;	28 0
RS Scuti	43.7	−10 21	9.3—10.3	0 15.9	13 2;	26 9;	8 16;	21 23
β Lyrae	46.4	+33 15	3.4— 4.1	12 21.8	13 17;	26 14;	8 12;	21 10
U Scuti	18 48.9	−12 44	9.1— 9.6	0 22.9	7 11;	26 13;	5 3;	24 5
RX Draconis	19 01.1	+58 35	9.3—10.2	1 21.4	7 8;	22 12;	6 15;	21 19
RV Lyrae	12.5	+32 15	11. —12.8	3 14.4	8 12;	22 22;	6 7;	20 17
RS Vulpec.	13.4	+22 16	6.9— 8.0	4 11.4	5 19;	23 17;	10 15;	28 13
U Sagittae	14.4	+19 26	6.5— 9.0	3 09.1	11 2;	24 15;	7 3;	20 16
Z Vulpec.	17.5	+25 23	7.3— 8.5	2 10.9	6 11;	21 4;	4 22;	19 15
TT Lyrae	24.3	+41 30	9.3—11.6	5 05.8	6 9;	22 3;	6 20;	22 14
UZ Draconis	26.1	+68 44	9.0— 9.8	1 15.1	12 3;	25 4;	7 5;	20 6
SY Cygni	19 42.7	+32 28	10 —12	6 00.2	6 18;	24 18;	11 19;	29 19
WW Cygni	20 00.6	+41 18	9.3—13.4	3 07.6	11 13;	24 20;	7 2;	20 9
SW Cygni	03.8	+46 01	9. —11.7	4 13.8	6 7;	24 14;	11 20;	30 4
VW Cygni	11.4	+34 12	9.8—11.8	8 10.3	5 7;	22 4;	8 1;	24 21
RW Capric.	12.2	−17 59	8.8—10.6	3 09.4	8 2;	21 16;	11 0;	24 14
UW Cygni	19.6	+42 55	10.5—13	3 10.8	14 13;	28 8;	11 3;	24 23
V Vulpec.	32.3	+26 15	8.2—9.8	37 19.0		27 13		
W Delphini	33.1	+17 56	9.4—12.1	4 19.4	3 13;	22 19;	11 0;	30 5
RR Delphini	38.9	+13 35	10.5—11.8	4 14.4	3 11;	21 21;	9 6;	27 16
Y Cygni	48.1	+34 17	7.1— 7.9	1 12.0	3 10;	18 10;	2 9;	17 9
WZ Cygni	49.3	+38 27	9.9—10.8	0 14.0	11 7;	23 0;	9 13;	21 5
RR Vulpec.	20 50.5	+27 32	9.6—11.0	5 01.2	3 14;	23 19;	2 21;	23 2
VV Cygni	21 02.3	+45 23	12.1—13.8	1 11.4	6 16;	21 11;	5 5;	20 0
AE Cygni	09.0	+30 20	10.8—11.4	0 23.3	3 19;	23 4;	11 13;	30 22
RY Aquarii	14.8	—11 14	8.8—10.4	1 23.2	8 16;	24 10;	1 7;	17 0
UZ Cygni	55.2	+43 52	8.9—11.6	31 07.3		31 10		31 18
RT Lacertae	21 57.4	+43 24	9.1—10.5	5 01.7	3 6;	23 13;	2 17;	23 0
RW Lacertae	22 40.6	+49 08	10.2—11.2	5 04.4	7 17;	23 7;	7 20;	23 9
X Lacertae	22 45.0	+55 54	8.2— 8.6	5 10.6	10 12;	26 20;	12 4;	28 12
TT Androm.	23 08.7	+45 36	11.3—12.6	2 18.3	3 23;	20 14;	6 4;	22 18
Y Piscium	29.3	+ 7 22	9.0—12.0	3 18.4	3 10;	18 12;	2 13;	17 14
TW Androm.	23 58.2	+32 17	8.6—11.5	4 02.9	5 7;	21 19;	7 6;	23 18









MAXIMA OF VARIABLE STARS, H. C. BANCROFT, JR.

New Variable Stars.—A new variable 13.1914 Herculis was found by Mme. L. Ceraski on March 3. The position of this star for 1900 is $\alpha = 17^h\ 32^m\ 22^s$, $\delta = +\ 34°\ 14'$. The star is rather faint, its range being from $11^m.0$ to $11^m.7$. The type of this variable is undetermined at present.

In *A. N.* 4726 a new variable 14.1914 Pegasi is announced by S. Enebo. This is the star BD + 17°4819. The period of this variable is in the neighborhood of 60 days, and its range is from $8^m.5$ to $9^m.4$.

In *A. N.* 4727, in connection with observations of other variables, Professor K. Bohlin calls attention to a new variable 15.1914 Ursae Majoris. This is the star BD + 41°2206. It varies between the limits $9^m.0$ and $9^m.5$. The period is long, probably about 112 days.

In *A.N.* 4728 four new variables discovered by Mme. L. Ceraski are announced:

1. 16.1914 Leonis Minoris in position for 1900 $\alpha = 10^h\ 39^m\ 10^s.7$, $\delta = +\ 26°\ 33'\ 40''$. It varies from 11^m to $12^m.5$ in a period of 87½ days.

2. 17.1914 Cancri, in position for 1900 $\alpha = 9^h\ 13^m\ 9^s.7$, $\delta = 29°\ 29'\ 13''.1$. It varies from $9^m.5$ to 11^m; its period is probably short.

3. 18.1914 Herculis, in position for 1900 $\alpha = 17^h\ 25^m\ 53^s$, $\delta = +\ 18°\ 0'$. It varies from $9^m.3$ to $12^m.5$ in a period of approximately 222 days.

4. 19.1914 Herculis, in position for 1900 $\alpha = 16^h\ 8^m\ 17^s.9$, $\delta = +\ 29°\ 9'\ 19''.0$. It varies from 10^m to $12^m.5$; its period has not been determined.

COMET AND ASTEROID NOTES.

Comet 1913 *f* (Delavan).—I am sending parabolic elements of comet 1913 *f* (Delavan), which I have computed from observations of Dec. 17.6018, Jan 31.6316, and Mar. 17.6649, by Hussey, Aitken and Haynes respectively. The solution originally undertaken was a general one, but it was soon seen that the eccentricity was sensibly equal to one, and parabolic elements were therefore computed. The error of the parabolic assumption is not sufficiently great to seriously affect the accuracy of an ephemeris computed from the resulting elements. The elements and constants for the equator follow. According to the last observation obtainable the elements represented to $\alpha + 3''$, $\delta + 3''$, in the sense O—C.

$$\left.\begin{aligned} T &= 1914\ \text{Oct.}\ 26.24100\ \text{G. M. T.} \\ \omega &= 97°\ 28'\ 51''.8 \\ \Omega &= 59\ \ 11\ \ 48\ \ .0 \\ i &= 68\ \ 02\ \ 46\ \ .4 \end{aligned}\right\}\ 1914.0$$
$$\log q = 0.042908$$

CONSTANTS FOR EQUATOR OF 1914.0.

$$x = r\ [9.781358]\ \sin\ (219°\ 34'\ 19''.3 + v)$$
$$y = r\ [9.909229]\ \sin\ (201\ \ 16\ \ 32\ \ .0 + v)$$
$$z = r\ [9.994791]\ \sin\ (117\ \ 43\ \ 14\ \ .5 + v)$$

MAXWELL W. ALLEN.

Comet 1913 *f* (Delavan).—This comet will begin to emerge from behind the Sun about the first of July, and will become visible toward the northeast about an hour before sunrise. It is likely to increase rapidly in brightness and may become conspicuous to the naked eye, but this will not occur until the latter part of August or in September.

The course of the comet during July will be northeastward through Taurus and Auriga.

EPHEMERIS OF COMET 1913 *f* (DELAVAN).

[Computed by Professor Wilson and Miss Hawkes from the elements by Einarsson and Nicholson. See P.A. March 1914, page 184.]

Gr. M. T.	α h m s	δ ° ′	log *r*	log Δ	Br.
June 18.5	4 28 21	+26 10.9	0.3508	0.5035	4.11
22.5	34 56	27 11.4	.3417	.4944	4.47
26.5	41 51	28 13.4	.3324	.4849	4.87
30.5	49 05	29 16.9	.3230	.4748	5.33
July 4.5	4 56 42	30 22.6	.3134	.4642	5.85
8.5	5 04 42	31 29.9	.3036	.4532	6.44
12.5	13 09	32 39.4	.2935	.4417	7.11
16.5	22 07	32 50.8	.2832	.4296	7.88
20.5	31 40	35 04.6	.2728	.4170	8.76
24.5	41 52	36 20.6	.2621	.4039	9.77
28.5	5 52 48	+37 39.3	0.1513	0.3904	10.98

Brightness = 1.00 on date of discovery Dec. 17,1913.

Comet 1906 IV Kopff, Definitive Elements.—Mr. Giovanni Zappa in a memoir published at Rome in 1913 gives the results of a definitive calculation of the elements of comet 1906 IV from all the published observations. He finds the period to be 6.5846 years. The comet should have returned to perihelion in December 1912 but was then in unfavorable position for observation.

The final elements are

Epoch and osculation 1906 October 10.5 Berlin mean time.

$\omega = 19^\circ\ 46'\ 43''.76$
$\Omega = 263\ 40\ 40\ .26$ } 1906.0
$i = 8\ 42\ 45\ .39$
$\phi = 31\ 05\ 57\ .86$
$\mu = 538''.885$
$M = 24^\circ\ 04'\ 20''.19$

New Comet 1914 *b* (Zlatinsky).—A cablegram from Kiel to Harvard College Observatory on May 17 announced the discovery of a new comet by Zlatinsky at Mitau (Milan?). Its position was observed by Dr. Schorr at Bergedorf on May 16, when the comet was quite near to the star α Persei. The cablegram reports the comet as visible to the naked eye, but as the comet was seen at Goodsell Observatory on the evening of May 18 it was at so low an altitude that it could hardly be distinguished with the aid of opera glasses, so that it cannot be called a conspicuous comet. It has a distinct nucleus, surrounded by dense nebulosity, with a faint broad tail running out from all parts of the head. The following observations are at hand:

Greenwich Mean Time	α h	m	s	δ °	′	″	Observer	Place
May 16.4381	3	17	37.7	+49	51	07	Schorr	Bergedorf
17.3974	3	38	23.9	+49	57	58	Vanderbilt	Utrecht
18.6630	4	07	53.7	+49	38	37	Wilson	Northfield
21.6223	5	20	08.3	+46	20	08	Wilson	Northfield

From the observations on May 16, 18 and 21 Professors Wilson and Gingrich have calculated the following elements and ephemeris. The elements are only approximate and the ephemeris, extending so far ahead, may not represent the course of the comet very closely, but it indicates that the comet will move rapidly southeastward and, by the time this number of POPULAR ASTRONOMY reaches its

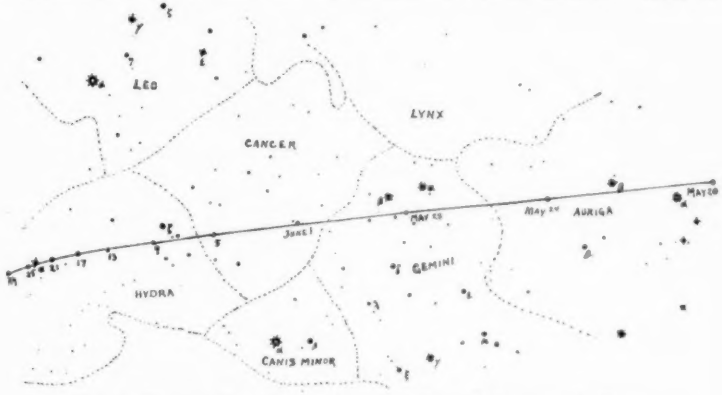


FIG. 1. DIAGRAM SHOWING THE APPARENT PATH OF ZLATINSKY'S COMET THROUGH THE CONSTELLATIONS.

readers in America, will have passed through Auriga and Gemini, and into Cancer. During June the motion will gradually slow up and at the end of the month the comet will be somewhere in the vicinity of α Hydræ. The apparent course is shown upon the chart, Figure 1.

PRELIMINARY ELEMENTS OF COMET 1914 *b* (ZLATINSKY).
Computed by Wilson and Gingrich.

$T = 1914$ May 8.373 Gr. M. T.
$\omega = 116° 19'.8$
$\Omega = 32 \ 35.7$
$i = 113 \ 02.0$
$\log q = 9.73482$

EPHEMERIS.

Greenwich Midnight 1914	True α h	m	s	True δ °	′	log r	log Δ	Brightness
May 16.5	3	18	56	+49	52.1	9.7596	9.7933	1.00
20.5	4	52	56	+48	02.8	9.7861	9.7400	1.13
24.5	6	23	02	+39	55.2	9.8176	9.7235	1.06
28.5	7	26	13	+28	35.3	9.8514	9.7496	0.84
June 1.5	8	06	00	+18	07.4	9.8856	9.8035	0.53
5.5	8	31	36	+ 9	56.6	9.9191	9.8667	0.34
9.5	8	49	05	+ 3	49.2	9.9512	9.9289	0.22
13.5	9	01	44	− 0	47.5	9.9817	9.9862	0.15
17.5	9	11	28	− 4	21.7	0.0105	0.0378	0.11
21.5	9	19	18	− 7	12.3	0.0376	0.0839	0.07
25.5	9	25	54	− 9	33.1	0.0631	0.1252	0.05
29.5	9	31	38	−11	31.3	0.0871	0.1623	0.04

The reason for the rapid movement of the comet and its quick waning in brightness will appear from the diagram Figure 2. The orbit of the comet is tilted at an angle of 113° to the plane of the earth's orbit, so that it is moving backward (retrograde) in longitude. When it was at perihelion, May 8, the comet and earth were moving roughly toward each other; on May 24 they passed nearest each other and are now separating. By July 1 the comet will be so far away that it will be very faint and perhaps beyond the reach of small telescopes.

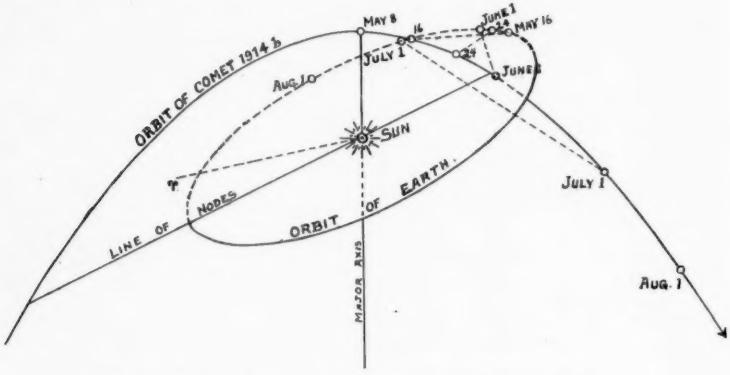


FIG. 2. DIAGRAM OF THE ORBIT OF ZLATINSKY'S COMET 1914 *b*.

A cablegram received May 22 from Perrine at Cordoba, South America, states that the orbit of Zlatinsky's comet is similar to that of the comet discovered by Miss Herschel in 1790. There were two comets discovered by Miss Herschel in that year, the second, 1790 III, being doubtless the one referred to. The elements ω, Ω and i agree very closely, but the perihelion distance differs too much to admit of identity of the two comets, if the above elements are anywhere near correct.

COMPARISON OF ELEMENTS

	Zlatinsky 1914 *b*	C. Herschel 1790 III
	° ′	° ′
ω	116 20	119 27
Ω	32 36	33 11
i	113 02	116 08
log q	9.7348	9.9020

Elements and Ephemeris of Comet *b* 1914 (Zlatinsky).

The results given below were obtained from the following observations:

1914 Gr. M. T.	Comet's apparent α	Comet's apparent δ	Observer
	h m s	° ′ ″	
May 16.4381	3 17 37.7	+49 51 07	Schorr, Hamburg
May 17.3974	3 38 23.9	+49 57 58	van der Bilt, Utrecht
May 18.6991	4 08 44.6	+49 37 36	Aitken

ELEMENTS

$T = 1914$ May 8.3834 Gr. M. T.
$\omega = 116° 21'.9$
$\Omega = 32 \ 36.0$ } 1914.0
$i = 112 \ 59.5$
$q = 0.54301$

O—C	I	III
$\cos\delta\,\Delta\alpha$	0″	−1″
$\Delta\delta$	+7	−1

CONSTANTS FOR THE EQUATOR 1914.0

$x = r\,[9.93869]\sin(192° \ 20'.4 + v)$
$y = r\,[9.91968]\sin(259 \ 52.6 + v)$
$z = r\,[9.87221]\sin(133 \ 05.4 + v)$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1914	True α h m s	True δ ° ′	log Δ	Br.
May 20.5	4 52 57	+48 02.2	9.7401	1.09
21.5	5 17 17	46 33.6		
22.5	5 40 42	44 40.2		
23.5	6 02 42	42 25.7		
24.5	23 00	39 54.3	9.7235	1.01
25.5	41 27	37 10.5		
26.5	6 58 04	34 19.6		
27.5	7 12 55	31 26.4		
28.5	26 08	28 34.3	9.7496	0.77
29.5	37 53	25 46.4		
30.5	48 19	23 04.8		
May 31.5	7 57 37	20 31.2		
June 1.5	8 05 55	18 06.3	9.8034	0.51
2.5	13 21	15 50.3		
3.5	20 02	13 43.3		
4.5	26 04	11 45.0		
5.5	31 32	9 55.2	9.8666	0.33
6.5	36 30	8 12.9		
7.5	41 01	6 38.2		
8.5	45 10	5 10.0		
9.5	48 59	3 47.9	9.9288	0.21
10.5	52 30	2 31.4		
11.5	55 46	1 20.0		
12.5	8 58 49	+ 0 13.3		
13.5	9 01 40	− 0 49.1	9.9861	0.14
14.5	04 20	1 47.7		
15.5	06 50	2 42.7		
16.5	09 11	3 34.5		
17.5	11 24	4 23.3	0.0377	0.10
18.5	13 30	5 09.4		
19.5	15 29	5 53.0		
20.5	17 24	6 34.5		
June 21.5	9 19 15	− 7 13.7	0.0838	0.07

Brightness May 17 = 1.00

R. T. CRAWFORD.
SOPHIA H. LEVY.

Berkeley Astronomical Department,
May 20, 1914.

Lick Observatory Bulletin, No. 254.

COMMUNICATIONS.

The Partial Eclipse of the Moon, March 11.—I observed the partial eclipse of the moon on March 11 here under very favorable weather conditions. The shadow, which entered the moon's surface at 9:42 E.S.T., was very dark in color at first, due to contrast with the brilliancy of the lighted part, but as the eclipse progressed it seemed to lighten in color. At 11:13, the moment of greatest eclipse, it was light enough to render the chief surface details clearly visible in a field-glass. The half next to the thin illuminated crescent was of an ashen gray, while the half deeper in the shadow was of a varnished red brown. This latter color, apparently that of the core of the shadow, was visible for only about forty minutes at the time of greatest eclipse. The sky, even near the horizon, was entirely clear of clouds throughout the eclipse.

GEORGE F. NOLTE.

Newton, Mass., Mar. 22, 1914.

The Partial Eclipse of the Moon, March 11.—The afternoon of March 11 in the city of Mexico was very cloudy and rather rainy. In spite of this fact, I conveniently arranged my Zeiss telescope, so beloved by my husband, the late Professor Luis G. León, and awaited impatiently the hour of the eclipse.

At 7 o'clock a terrible hail storm fell in the city of Mexico and part of the federal district.

The rainy season in Mexico begins in May or June, but it is almost a general rule here that in the month of March, there falls at least one rain storm in which the quantity of water exceeds that of any other storm during the rainy season. But it is very seldom that these storms occur in the night and especially accompanied by hail, as occurred on the night of March 11.

At 7:45 it began to clear, and at 8, the hour of the first contact with the shadow the moon was shining splendidly on the city, giving it a most beautiful aspect with its avenues all covered with hail.

The shadow of the earth began to cover slowly the Ocean of Rains, the Sea of Serenity, the Sea of Tranquility, the Sea of Crisis, the Sea of Fecundity and trying to hide the craters, came at 9:30 p.m. to the beautiful Tycho, where it seemed to linger. The moon acquired at that moment a reddish tint, similar to that of Mars with its casket of Polar snow.

Through the shadow one could distinguish the seas and craters, as if seen through ashy light.

At 10:15 the clouds completely covered the lunar disk and it was not possible to see the end of this interesting phenomenon.

DOLORES G. VDA. DE LEÓN.

Mexico, Mar. 13, 1914.

A Beautiful Shooting Star.—On Sunday March 15, a beautiful shooting star of an emerald color, crossed the city of Mexico. It sprang from the head of Ursa Major, crossed the dragon and slowly lost itself in the constellation of Auriga, It left no luminous trail and made no noise, but it is estimated that its light exceeded that of a first magnitude star.

DOLORES G. VDA. DE LEÓN.

Earthshine on a Gibbous Moon.—Who, amateur or professional, in showing the moon with a telescope, has not been asked "But can't you see the other half?" The usual answer is "No", but the "other half" can at times be seen. The phenomenon of earthshine is of course known to us all, but I have found that it remains visible under certain conditions much nearer to full moon than I had supposed.

My notice was attracted in this direction in January of last year. I had been hunting comets and swung the telescope down to where the moon was rising behind the dome of the photographic telescope some two hundred feet distant. When the preceding limb of the moon appeared I was surprised at the apparent brightness of the earthshine, but not more so than when it faded to a mere fraction of that brightness as the cusps of the moon slid into view. This last contained the key to the situation. As the solar corona becomes visible when the moon hides the sun's disk in total eclipse, so the earthshine on the moon becomes visible when the light of the directy illuminated portion of its disk is screened off by a sufficiently distant object, but since the moon is less brilliant, the conditions are less exacting, and a screen a few feet from the observer is often sufficient. It is only necessary that the observer's eye (or the objective of his telescope) be so placed that no light from the directly illuminated part of the disk falls upon it. An elevated water tank, especially a spherical one, makes a good screen if one can get into its shadow. I usually use one or other of the domes here.

I have found considerable interest in seeing how near to the full this earthshine may be seen. To compare observations I take for the respective times the earth's selenographic longitude and the sun's selenographic colongitude (Am. Eph., p. 610,) and add 90° to their sum. This angle, or 360° minus this angle, gives approximately the visible illuminated arc of the moon's equator. I have twice succeeded in seeing earthshine with this quantity greater than 120°. Over and above its interest as an experiment, this may perhaps help some of us in illustrating to our friends (who so often want explanations) the "why" of eclipse expeditions. A long series of observations both before and after full might even become evidence, one way or the other, on the question of whether or not any part of the light thus seen to be due to phosphorescence.

BERNHARD H. DAWSON.

Observatorio Nacional,
LaPlata, Rep. Argentina.
1914 March 12.

Comet 1914 *a*.—I wish to report that I observed Comet *a* 1914 (Kritzinger) on 1914 May 16, 14^h. I found it fairly conspicuous in a 4-inch telescope, but there is very little central condensation.

At the time of my observation it was near the ring nebula in Lyra, and it was therefore easy to compare the two. I found it more difficult for a 4-inch telescope than the nebula.

DR. WILL CASSELL.

Wytheville, Va., 1914 May 17.

NOTES FOR OBSERVERS.

Monthly Report of the American Association of Variable Star Observers Apr.-May, 1914.—With the advent of more seasonable weather for observing, it is gratifying to note an increase in the number of observations contributed, and a highly creditable monthly report.

We welcome to our ranks two new members: Mr. Charles B. Lindsley, "Ly" of Berea, Ky., and Mr. George A. Winterbottom, "Wn" of Springfield, Mass. Both of these gentlemen observe with three-inch refractors. Mr. Lindsley is to be congratulated on his first report of 49 observations of 16 variables that are in unusual accord with those of more experienced observers, for one who has just taken up the work.

Mr. Bancroft again leads with a splendid total of 255 observations of 98 variables. Mr. Lacchini was a close second with 237 observations, a remarkable showing considering the fact that his glass is only a 2⅜″ aperture. Mr. Lacchini deserves great credit for a large number of early morning observations which are specially valuable. Mr. McAteer is also to be commended for his zeal in this direction, and for his being the only member to secure observations of the recent maximum of 213843 SS Cygni.

The Harvard College Observatory has recently confirmed our observation that the 8.7 comparison star on the field of 043274 X Camelopardalis is brighter than the 8.5. It is not known as yet whether this is due to a clerical error or an actual variance in the light of one of these stars.

One of the most interesting observations of late is that of a lower minimum of 070310 R Can. Min. than any previously recorded. The irregularity of the long period variables adds zest to their observation.

The special effort that we are making to observe the neglected variables goes steadily forward. During the past month 37 of these stars were observed as compared with 24 last month, and 170 observations secured, 100 more than appear in last month's report. These fields are difficult for observers with small apertures, but this renders the work more interesting, and in annexing these variables to our observing list there is the satisfaction that their observation is of particular value.

The thanks of the Association are due Dr. Edward Gray for his excellent article on the attractiveness of variable star observing, in the April 4th issue of "*Scientific American*". The steady growth of our membership is largely due to those of our members who have endeavored to call the attention of the public to the practical nature of the work we are doing.

The rapid rise of 103769 R Ursae Majoris, although not unusual in the case of this variable, is a special feature of this month's report. The variable rose three magnitudes in a month, an increase of fifteen times in brilliance. Gore says of this variable: "It rises with astonishing rapidity to maximum but fades away slowly. The spectrum is of the third type. At the maximum of 1901 Peek found that the color changed in two months from deep dull ruddy to nearly white."

Variable Star Observations Apr.-May, 1914.

003179
Y Cephei

Mo.	Day	Est.	Obs.
4	5	11.7	Ba
	10	11.8	Ba

004047
U Cassiop.

3	31	8.8	L
4	6	8.2	L
	10	8.2	L
	22	8.2	L

004958
W Cassiop.

4	5	8.9	Ba
	13	8.8	Ba

014958
X Cassiop.

4	13	11.0	Ba
	14	11.3	L
	17	9.8	B
	22	10.8	L
5	2	10.1	Y

015354
U Persei

4	13	8.2	Ba

021558
S Persei

4	13	11.5	Ba

024356
W Persei

3	31	9.7	L
4	5	9.0	Ba
	10	9.1	Ba
	13	8.8	Ba
	14	9.7	L
	17	8.8	Ba
	22	9.7	L
	23	9.0	Ba
	28	9.0	Ba

032043
Y Persei

3	28	8.5	R
4	5	8.6	Ba
	10	8.5	Ba
	11	8.2	R
	13	8.6	R
	13	8.6	Ba
	17	8.4	Ba
	19	8.8	R
	23	8.5	Ba
	28	8.5	Ba

033362
U Camelop.

4	5	7.2	Ly
	13	7.2	Ly
	18	7.3	Ly
	28	7.4	Ly

042215
W Tauri

Mo.	Day	Est.	Obs.
4	3	11.2	B
	6	11.6	Bb
	13	11.3	B
	13	11.6	Ba

042309
S Tauri

4	22	9.8	Y

043065
T Camelop.

5	1	8.2	Y

043208
RX Tauri

4	3	10.1	Bb
	3	10.1	B
	4	10.4	Bu
	6	10.3	Bb
	6	10.4	Bu
	10	10.4	Ba
	12	10.6	Bu
	13	10.4	B
	18	10.6	Bu
	23	11.2	B

043274
X Camelop.

4	1	7.8	L
	3	7.5	B
	4	8.4	Bu
	5	7.5	Ba
	6	8.2	Bu
	10	7.4	B
	12	8.2	Bu
	12	7.8	O
	13	7.8	Ba
	13	7.8	L
	16	7.9	L
	17	7.7	Ba
	17	7.8	O
	18	8.2	Bu
	18	8.0	G
	21	7.8	O
	21	7.4	B
	22	8.0	L
	23	7.9	Ba
	23	7.9	G
	24	8.1	L
	27	8.2	Ba

044617
V Tauri

4	3	12.4	B
	13	13.0	B

045514
R Leporis

Mo.	Day	Est.	Obs.
4	2	7.2	G
	4	7.2	Bu
	6	8.0	L
	10	7.7	L

050953
R Aurigae

4	2	8.9	G
	4	8.8	Bu
	5	8.8	Ba
	5	9.4	P
	6	8.8	Bu
	10	9.0	B
	10	8.9	Ba
	12	9.2	Bu
	16	9.0	G
	18	9.4	Bu
	18	9.1	Ba
	23	9.2	G
	27	9.2	Ba

052034
S Aurigæ

4	5	9.2	Ba
	10	9.2	B
	10	9.7	M
	10	9.8	L
	12	10.4	P
	13	9.5	Ba
	16	10.0	L
	18	9.3	Ba
	21	10.1	P
	21	9.2	B
	22	10.2	L
	27	9.4	Ba

052036
W Aurigæ

4	5	12.1	Ba
	13	12.3	Ba

052404
S Orionis

4	6	12.2	Bb
	13	11.8	Ba

053068
S Camelop

5	1	9.8	Y

053005a
T Orionis

4	12	9.5	M
	13	9.8	Ba

053531
U Aurigae

4	13	12.9	Ba
	21	11.8	Y
	28	11.5	Ba
5	2	9.8	Y

054920
U Orionis

Mo.	Day	Est.	Obs.
4	1	10.1	L
	4	9.8	Bu
	5	9.2	Ba
	6	9.3	Bb
	6	9.8	Bu
	10	9.3	L
	13	9.0	Ba
	14	8.6	L
	16	8.6	L
	17	8.6	Hu
	17	8.3	S
	18	8.4	Ba
	21	8.3	L
	21	8.0	Hu
	23	7.8	Ba
	24	7.9	L
	27	7.6	Ba

055353
Z Aurigae

5	1	9.8	Y

060450
X Aurigae

4	2	8.9	G
	4	8.4	Bu
	5	9.2	Ba
	6	8.7	Bb
	6	8.6	Bu
	10	9.8	B
	12	8.6	Bu
	13	10.3	Ba
	16	9.1	G
	18	8.4	Bu
	18	11.0	Ba
	21	11.0	B
	21	10.7	V
	23	9.3	G
	23	12.0	Ba
	27	12.0	Ba

060547
SS Aurigae

4	21	10.9	L
	22	10.9	L
	23	11.7	Ba
	23	11.6	L
	23	9.9	G
	24	12.0	L

061647
V Aurigae

4	13	10.8	V
	13	11.0	Ba
	21	11.3	Y
	28	11.4	Ba

061702
V Monoc.

4	4	7.5	Bu
	5	7.8	Ba
	6	7.5	Bu

V Monoc.

Mo	Day	Est.	Obs.
4	10	8.1	Ba
	12	7.5	Bu
	16	8.5	G
	18	7.6	Bu
	18	8.5	Ba

062808
Z Aurigae

4	16	8.4	G
	21	8.3	G

063159
U Lyncis

4	5	10.2	Ba
	10	9.9	Ba
	13	10.1	O
	13	9.8	Ba
	17	9.8	Ba
	21	9.6	Hu
	21	10.3	O
	23	9.8	Ba
	27	9.8	Ba
	30	9.8	Ba

063558
S Lyncis

4	5	11.9	Ba
	10	11.4	Ba
	13	11.0	Ba
	13	11.3	O
	17	10.8	Ba
	21	10.7	O
	21	10.3	Hu
	23	10.2	Ba
	27	10.1	Ba
	30	10.3	Ba
5	1	10.1	Y

064030
X Geminorum

4	5	9.0	Ba
	13	8.8	Ba
	18	9.0	Ba
	21	9.1	V
	22	9.0	Y
	23	9.0	O
	23	8.7	Ba
	28	8.7	Ba
	29	8.7	G

064932
Nova Gemin.

4	13	11.4	L
	14	11.4	L
	21	11.4	L
	24	11.2	L

VARIABLE STAR OBSERVATIONS Apr.-May, 1914.—Continued.

065208
X Monoc.

Mo.	Day	Est.	Obs.
3	28	7.9	R
	30	7.2	R
	31	7.8	L
4	1	7.8	R
	10	7.8	L
	11	8.2	R
	13	8.4	R
	15	8.4	R
	16	7.9	G
	16	8.1	L
	17	8.4	R
	18	8.0	Ba
	18	8.4	R
	19	8.2	R
	21	8.0	G
	22	8.4	L
	23	8.5	R

065355
R Lyncis

4	19	9.0	G
5	1	9.5	Y

070122a
R Gemin.

4	17	12.3	Hu

070310
R Can. Min.

4	1	10.6	L
	2	10.5	G
	4	10.6	Bu
	12	10.8	O
	13	10.8	L
	16	10.9	L
	17	10.8	O
	17	10.7	Ba
	17	11.0	G
	21	10.8	L
	22	10.8	O
	23	10.0	B
	23	10.7	Ba
	24	10.8	L
	28	10.3	Ba

071713
V Gemin.

4	13	9.9	V
	13	9.7	Ba
	19	8.8	G

072708
S Can. Min.

3	28	8.2	R
	30	8.3	R
	31	8.1	L
4	1	8.2	R
	2	8.1	G
	4	8.4	Bu
	4	8.5	L
	5	8.4	Ma
	5	8.1	G
	5	8.5	P
	6	8.4	Bu
	6	8.2	Bb
	10	8.7	L
	10	8.6	M
	11	8.3	Bb
	11	8.3	R
	12	8.7	M
	12	8.8	O
	12	8.6	Bu
	13	8.5	R
	13	8.4	Ba
	14	8.7	L
	15	8.6	R
	16	8.3	G
	16	8.6	Ly
	17	8.5	L
	17	8.5	R
	17	8.7	S
	17	8.8	O
	18	8.7	Ba
	18	8.7	Ly
	18	8.5	R
	18	8.6	Bu
	19	8.5	R
	21	9.0	O
	21	8.8	L
	21	8.6	G
	21	8.6	Ly
	23	8.7	R
	23	8.8	O
	23	9.4	P
	24	8.8	B
	24	8.8	Ly
	24	9.3	L
	25	9.3	R
	26	8.8	Ly
	27	8.9	M
	28	8.8	Ba
	29	8.8	G
5	1	8.6	Ly

072811
T Can. Min.

4	13	10.8	V
	13	11.2	Ba
	18	11.5	Ba
	22	11.8	Y

073508
U Can. Min.

4	13	13.0	Ba

073723
S Gemin.

4	3	12.0	Hu
	13	12.6	Ba
	17	12.4	Hu
	22	12.5	Y
	28	13.0	Ba

074323
T Gemin.

4	6	8.6	G
	13	8.5	Ba
	13	8.5	V
	14	8.9	O
	17	8.6	Hu
	17	8.9	O
	18	8.5	Ba
	19	8.8	G
	21	8.9	O
	21	8.9	Y
	23	8.9	O
	28	8.6	Ba
5	6	9.1	O

074922
U Gemin.

4	13	13.3	B

081112
R Cancri

3	31	10.4	L
4	4	9.8	Bu
	5	9.8	Ba
	6	9.8	Bu
	10	9.5	Ba
	12	9.6	Bu
	13	10.0	L
	16	10.0	L
	17	9.8	Hu
	17	10.0	Ba
	18	9.4	Bu
	21	10.0	O
	21	10.0	L
	23	10.0	P
	23	10.0	Ba
	24	9.8	L
	27	9.8	Ba
	30	9.4	Ba

081633
T Lyncis

4	2	11.8	G

081617
V Cancri

4	13	12.6	Ba

082405
RT Hydrae

4	1	7.7	L
	4	7.6	Bu
	6	7.9	Bb
	6	7.4	Bu
	10	7.9	L
	11	8.2	Bb
	12	7.6	Bu
	13	7.8	B
	16	7.7	L
	17	7.7	G
	18	7.6	Ba
	18	7.6	Bu
	20	7.9	B
	22	7.8	L
	23	7.9	G
	28	7.8	Ba

083019
U Cancri

4	11	10.7	V
	13	11.4	Ba
	23	11.6	O
	28	12.3	Ba

084803
S Hydrae

4	12	10.2	B
	13	11.8	B
	17	12.3	Hu
	28	12.0	Ba

085008
T Hydrae

4	2	8.9	G
	4	9.4	Bu
	6	9.4	Bu
	11	8.2	V
	12	9.0	Bu
	17	8.6	G
	17	9.0	Hu
	18	8.5	Ba
	18	8.8	Bu
	23	8.3	G

085120
T Cancri

3	31	9.3	L
4	4	8.8	Bu
	6	8.4	Bb
	6	8.8	Bu
	11	8.5	Bb
	12	9.0	Bu
	13	9.2	L
	14	9.2	L
	18	8.4	Ba
	18	9.0	Bu
	21	9.3	L
	28	8.2	Ba

090425
W Cancri

4	13	9.5	Ba
	17	9.7	S
	17	9.4	O
	18	9.1	Ba
	21	9.0	V
	22	9.3	O
	23	8.7	B
	23	8.6	Ba
	27	8.5	Ba

093014
X Hydrae

4	13	11.4	Ba
	17	11.1	G
	23	11.1	G
5	2	10.9	Y

093934
R Leo. Min.

4	4	9.6	Bu
	6	9.6	Bu
	12	9.8	Bu
	13	9.5	Ba
	14	10.7	E
	17	10.2	Hu
	18	10.1	Ba
	18	10.0	Bu
	19	10.5	G
	28	10.4	Ba

094211
R Leonis

3	28	6.6	R
	30	6.6	R
	31	6.6	R
4	1	6.6	R
	2	6.6	G
	3	7.4	Bb
	4	6.8	L
	4	7.4	Bu
	5	7.8	Ma
	5	7.1	Ba
	5	6.5	G
	6	7.4	Bu
	10	7.0	L
	10	7.2	Ba
	11	6.7	R
	11	8.0	Bb
	12	7.1	M
	12	7.4	Bu
	12	7.4	P
	13	6.7	R
	13	7.0	O
	13	7.5	E
	13	7.6	Ly
	14	7.1	B
	14	7.1	L
	15	6.6	R
	16	6.7	G
	16	7.7	Ly
	17	7.3	Ba
	17	7.2	O
	17	7.7	L
	17	6.8	R
	17	7.5	S
	18	7.6	Bu
	19	6.9	R
	19	7.0	G
	21	8.1	Ly
	21	8.2	Ma
	22	7.5	O
	22	7.3	L

VARIABLE STAR OBSERVATIONS Apr.-May, 1914—Continued.

R Leonis

Mo.	Day	Est.	Obs.
4	23	7.0	Ba
	23	6.9	R
	23	8.1	P
	24	8.2	Ly
	25	6.8	R
	26	8.4	Ly
	27	8.0	M
	28	7.5	Ba
	29	8.5	Ma
	29	8.4	Ly
5	6	7.7	O

094622
Y Hydrae

4	2	6.0	G
	17	6.9	Ba
	17	6.0	G
	23	6.1	G

095421
V Leonis

4	17	11.9	Ba
	23	11.0	B
	23	11.8	Y
	28	10.5	Ba

103012
U Hydrae

3	31	5.0	L
4	2	5.0	G
	4	5.4	Bu
	6	5.4	Bu
	12	5.2	Bu
	13	5.6	L
	14	5.2	L
	17	5.3	L
	17	4.8	G
	18	5.4	Bu
	22	5.1	L
	23	4.8	G

103769
R Urs. Maj.

4	3	9.6	M
	5	8.7	Ba
	5	9.2	Ma
	10	8.4	Ba
	10	9.0	M
	12	8.5	M
	12	8.7	Ma
	13	8.4	Ba
	14	8.6	H
	17	8.5	O
	17	8.1	B
	17	8.2	Ba
	17	8.2	L
	19	8.3	M
	21	8.4	Ma
	21	8.3	O
	21	8.2	Hu

R Urs. Maj.

Mo.	Day	Est.	Obs.
4	21	8.2	S
	22	8.0	L
	23	8.0	Ba
	23	8.0	O
	23	8.2	M
	27	7.8	Ba
	27	8.1	M
	29	8.1	M
	29	8.2	Ma
	30	7.8	Ba
5	1	7.8	Ly
	2	8.0	M
	6	8.0	O
	7	8.1	M

104620
V Hydrae

4	1	6.2	L
	2	6.3	G
	4	6.6	Bu
	6	6.4	Bu
	12	6.6	Bu
	13	6.6	L
	17	6.2	G
	17	6.7	Ba
	17	6.6	L
	18	6.6	Bu
	22	6.6	L
	23	6.1	G

105517
R Crateris

4	16	8.0	G

110506
S Leonis

5	2	11.3	Y

120905
T Virginis

4	5	9.7	Ba
	17	9.7	Ba
	27	9.7	Ba
	30	9.3	Y

121418
R Corvi

4	5	11.9	Ba
	13	11.6	Ba
	13	11.6	B
	18	11.2	Ba
	21	11.2	B
	27	10.9	Ba
	30	10.9	Y

122001
SS Virginis

4	5	7.6	Bu
	9	7.8	Bu
	13	7.8	Bu
	14	7.5	O
	17	7.5	Ba
	21	8.0	Bu

SS Virginis

Mo.	Day	Est.	Obs.
4	27	7.5	Ba
5	2	8.2	Hu

122532
T Can. Ven.

4	5	10.6	Bu
	13	10.9	O
	17	10.5	G
5	2	11.0	Y

122803
Y Virginis

4	2	10.0	L
	5	9.5	Ba
	16	10.0	L
	17	9.7	Ba
	22	9.7	L
	27	9.8	Ba
	30	10.3	Y

123160
T Urs. Maj.

4	2	8.6	G
	3	8.1	M
	5	8.0	Ba
	5	8.0	Bu
	5	8.5	G
	9	8.0	Bu
	10	8.0	M
	10	8.0	Ba
	11	7.8	Bb
	12	8.0	M
	13	8.0	O
	13	7.8	Bu
	16	7.8	G
	16	8.1	Ly
	16	8.3	E
	17	8.0	O
	17	8.0	S
	17	8.1	B
	17	7.8	Ba
	17	7.8	Hu
	18	8.1	Ly
	19	7.9	M
	19	8.0	G
	21	8.0	Ly
	21	8.2	Ma
	21	7.6	Bu
	23	7.6	O
	23	7.8	Ba
	23	7.9	G
	24	8.3	Ly
	26	8.0	Ma
	26	8.2	Ly
	27	7.9	Ba
	28	7.7	M
	29	8.1	Ly
	29	8.1	G
5	2	8.0	M
	6	7.8	O
	7	8.3	M

123307
R Virginis

Mo.	Day	Est.	Obs.
4	3	10.9	Bb
	11	11.1	Bb
	17	11.2	Ba
	17	10.8	B
	17	10.5	S
	21	10.3	Hu
	21	10.8	L
	24	10.5	L
	27	10.1	Ba

123459
RS Urs. Maj.

4	23	13.4	Ba
	27	13.2	Ba
	30	13.3	Ba

123961
S Urs. Maj.

3	31	7.9	L
4	2	7.4	G
	3	8.5	M
	3	8.6	Bb
	5	8.0	L
	5	8.1	Ma
	5	7.8	Ba
	5	8.6	Bu
	5	7.5	G
	9	8.8	Bu
	10	8.6	M
	10	7.8	Ba
	10	8.6	L
	11	8.8	Bb
	12	8.0	Ma
	12	8.6	M
	13	8.4	O
	13	8.8	Bu
	16	8.3	G
	16	8.0	L
	16	8.4	Ly
	16	8.4	E
	17	8.4	O
	17	8.0	Ba
	17	7.9	B
	17	7.2	Hu
	17	8.7	S
	18	8.5	Ly
	19	8.5	G
	19	8.7	M
	21	8.9	Bu
	21	8.3	Ma
	21	8.6	Ly
	22	8.2	L
	23	8.1	Ba
	23	8.5	O
	23	8.5	G
	23	8.8	M
	24	8.5	Ly
	26	8.6	Ma
	26	8.5	Ly
	27	8.2	Ba

S Urs. Maj.

Mo.	Day	Est.	Obs.
4	28	8.9	M
	29	8.8	G
	29	8.6	Ma
	30	8.4	Ba
5	1	8.4	Ly
	2	8.6	M
	6	8.7	O
	7	8.9	M

124204
RU Virginis

4	17	11.5	Ba
	17	11.8	L
	22	12.0	L
	27	11.6	Ba

124606
U Virginis

4	17	10.1	S
	18	11.8	Ba
	18	10.7	G
	21	11.5	L

132202
V Virginis

4	13	8.8	B
	18	9.0	Ba
	21	8.9	B
	27	8.8	Ba
	30	9.1	Y

132422
R Hydrae

3	31	4.4	L
4	2	4.2	G
	2	4.4	L
	3	4.5	Bb
	5	4.8	L
	6	4.4	Bb
	13	4.7	L
	13	4.4	Bu
	14	4.7	L
	16	4.4	G
	16	4.7	L
	17	4.6	G
	17	4.7	L
	19	4.9	G
	21	4.4	Bu
	22	4.8	L
	23	5.0	G
	29	5.2	G

132706
S Virginis

3	31	9 6	L
4	2	10.0	L
	3	9.4	Bb
	5	9.6	Ba
	5	9.4	Bu
	6	9.7	Bb

VARIABLE STAR OBSERVATIONS Apr.-May, 1914.—Continued.

S Virginis

Mo.	Day	Est.	Obs.
4	9	9.6	Bu
	12	9.7	P
	13	10.0	L
	14	10.0	L
	17	9.9	Ba
	18	9.6	G
	21	10.4	L
	21	9.8	Bu
	24	10.5	L
	27	10.6	Ba
5	2	11.0	Hu

133273

T Urs. Min.

4	3	12.5	Bb
	6	12.5	Bb

133633

T Centauri

4	17	6.9	G
	18	6.7	G
	23	6.5	G

133674

V Urs. Min.

4	18	7.5	G

134440

R Can. Ven.

3	31	6.9	L
4	2	6.8	G
	3	7.7	M
	4	6.6	L
	5	6.8	L
	5	7.0	Ba
	5	7.2	Bu
	9	7.0	Bu
	10	6.9	L
	10	6.8	Ba
	10	7.0	M
	12	7.3	M
	13	7.0	Bu
	13	7.4	O
	13	7.9	E
	14	6.9	L
	16	6.8	L
	17	7.6	S
	17	7.5	O
	17	7.5	B
	17	7.0	Ba
	17	6.9	G
	18	7.3	Hu
	21	7.6	Ly
	21	6.8	Bu
	21	6.9	L
	23	7.5	O
	23	7.0	Ba
	24	7.0	L
	26	7.4	Ly
	27	7.3	Ba
	27	7.9	M
	28	8.0	M
	29	6.8	G

140412

Z Virginis

Mo.	Day	Est.	Obs.
4	30	12.5	Y

141567

U Urs. Min.

Mo.	Day	Est.	Obs.
3	31	8.4	B
4	2	8.4	G
	5	8.4	Ba
	5	8.7	Bu
	9	8.8	Bu
	10	8.4	Ba
	10	8.3	M
	13	8.2	O
	13	8.3	Ba
	13	9.0	Bu
	17	8.4	O
	17	8.5	Ba
	17	8.5	S
	18	8.6	G
	21	9.0	Bu
	23	8.7	Ba
	24	8.8	B
	27	8.7	Ba
	30	8.8	Ba
5	2	8.8	Hu

141954

S Boötis

Mo.	Day	Est.	Obs.
3	28	8.5	R
	31	8.5	L
4	3	8.0	Bb
	3	8.3	O
	3	8.4	M
	4	8.5	L
	5	8.5	Ba
	5	8.1	P
	5	8.7	Bu
	6	8.5	G
	9	8.8	Bu
	10	8.5	Ba
	10	8.9	L
	11	7.9	Bb
	12	8.7	O
	13	8.7	R
	13	9.0	Bu
	14	8.9	B
	14	8.8	L
	15	8.4	R
	16	8.5	G
	17	8.8	L
	17	8.7	Ba
	17	8.7	R
	17	9.0	O
	17	9.0	S
	18	8.6	R
	19	8.9	R
	21	8.8	Bu
	21	9.2	Ly

S Boötis

Mo.	Day	Est.	Obs.
4	22	8.5	Hu
	22	9.2	L
	23	8.9	R
	23	8.8	G
	23	9.1	Ba
	24	9.0	Ly
	24	8.9	L
	26	9.3	Ly
	29	9.0	Ma
	30	9.4	Ba
5	1	9.5	Ly

142205

RS Virginis

4	27	12.5	Ba

142539

V Boötis

3	31	9.1	L
4	2	8.7	G
	3	8.7	M
	3	8.5	O
	4	8.7	L
	5	8.6	P
	5	8.5	G
	5	9.0	Bu
	5	8.0	Ba
	6	8.9	L
	9	8.8	Bu
	10	8.6	L
	10	7.8	Ba
	13	8.2	O
	13	8.8	Bu
	14	8.1	B
	14	8.3	L
	16	8.1	G
	17	8.6	S
	17	8.1	O
	18	8.1	G
	18	7.8	Ba
	21	8.6	Bu
	21	8.3	L
	21	7.9	Ly
	22	8.0	Hu
	23	7.9	G
	24	8.2	L
	24	8.2	Ly
	26	8.1	Ly
	27	7.5	Ba
	29	8.0	M
	29	7.6	G

142584

R Camelop.

3	31	9.1	L
4	2	9.1	L
	2	8.5	G
	3	9.0	O
	5	8.6	Bu
	9	8.8	Bu

R Camelop.

Mo.	Day	Est.	Obs.
4	10	8.9	B
	10	9.2	L
	12	8.8	O
	13	9.0	Bu
	13	9.2	L
	16	9.6	L
	17	9.3	O
	18	9.0	Ba
	18	8.9	G
	21	9.3	O
	21	9.0	Bu
	22	9.6	L
	24	9.7	L
5	1	9.7	Ly

143227

R Boötis

4	5	10.4	Bu
	5	10.7	L
	5	10.9	P
	14	11.5	B
	14	11.6	L
	18	11.7	Ba
	22	12.0	L
	23	11.6	Ba
	30	11.5	M

144918

U Boötis

4	3	11.4	Hu
	5	11.5	Ba
	6	10.7	Bb
	11	10.8	Bb
	14	11.6	B
	18	11.7	Ba
	18	10.0	Hu
	23	11.4	B
	27	11.5	Ba
	30	11.3	Y

150519

T Librae

4	2	11.8	L

150605

Y Librae

4	18	12.2	Ba

151520

S Librae

4	14	10.8	L
	16	10.8	L
	18	10.6	Ba
	30	10.0	Y

151614

S Serpentis

4	23	11.7	Ba

151731

S Cor. Bor.

Mo.	Day	Est.	Obs.
4	3	8.5	M
	10	8.3	Ba
	13	8.8	R
	15	9.2	R
	17	8.5	O
	18	8.6	G
	18	9.2	R
	18	8.8	Ba
	19	8.9	R
	21	8.8	Ma
	22	8.8	O
	23	8.8	P
	23	8.8	R
	23	8.6	Ba
	26	9.0	Ly
	29	8.9	G
	30	8.7	Ba
	30	8.8	M
5	1	9.3	Ly

153378

S Urs. Min.

4	1	12.2	L
	10	11.5	Ba
	10	10.6	B
	13	11.5	L
	14	11.5	L
	17	11.1	Ba
	22	10.8	L
	22	10.3	Ba
	24	10.2	B
	27	10.4	Ba
	30	10.5	Ba
5	2	9.9	Hu

154428

R Cor. Bor.

3	31	6.0	L
4	1	6.0	L
	3	6.2	M
	3	6.3	Bb
	5	5.8	R
	5	5.8	Ba
	5	6.0	L
	6	6.0	G
	6	6.1	Bb
	10	6.0	L
	10	5.5	Ba
	11	6.0	Bb
	12	5.8	Ma
	13	6.0	L
	13	6.0	O
	13	6.0	Bu
	13	5.6	Ba
	14	6.0	L
	14	5.8	H
	16	6.0	G
	16	5.7	H
	17	5.8	Ba
	17	6.0	O

VARIABLE STAR OBSERVATIONS Apr.-May, 1914.—Continued.

154536
X Cor. Bor.

Mo.	Day	Est.	Obs.
4	23	12.4	Ba

154639
V Cor. Bor.

Mo.	Day	Est.	Obs.
4	13	8.6	Bu
	16	8.6	G
	18	8.7	G
	21	8.8	Bu
	22	9.0	Hu
	22	9.1	O
	23	9.2	G
	23	8.6	Ba
	25	8.8	Bu
5	3	9.3	M

154615
R Serpentis

Mo.	Day	Est.	Obs.
4	4	5.8	M
	19	6.1	M
	22	6.3	G
	23	6.3	O
	23	6.0	Ba
	25	5.6	Bu
5	3	6.4	M
	6	6.3	O

155847
X Herculis

Mo.	Day	Est.	Obs.
4	13	6.2	L
	23	6.3	L

160118
R Herculis

Mo.	Day	Est.	Obs.
4	23	9.0	Ba
5	2	8.0	Y

160210
U Serpentis

Mo.	Day	Est.	Obs.
4	23	8.9	Ba

160625
RU Herculis

Mo.	Day	Est.	Obs.
4	16	11.4	L
	23	11.3	Ba
	24	11.8	L

162119
U Herculis

Mo.	Day	Est.	Obs.
4	4	7.2	M
	16	7.2	G
	19	7.4	M
	21	7.7	S
	21	7.6	Ma
	23	7.6	Ba
	23	8.0	P
	23	7.1	G
	26	8.1	Ly
	27	8.0	M
	29	8.2	Ma
	29	8.2	Ly
	29	7.1	G
	30	8.1	M
5	1	8.2	Ly
	2	8.0	Y

162807
SS Herculis

Mo.	Day	Est.	Obs.
4	21	11.5	L
	23	11.1	Ba
5	2	9.4	Y

163137
W Herculis

Mo.	Day	Est.	Obs.
4	13	12.3	Ba
	23	13.0	Ba
5	2	13.0	Hu
	2	12.9	Y

163172
R Urs. Min.

Mo.	Day	Est.	Obs.
3	31	10.6	B
4	5	11.0	Bu
	10	10.4	Ba
	10	10.5	M
	24	9.7	B
	27	9.9	Ba
5	2	10.4	M

163266
R Draconis

Mo.	Day	Est.	Obs.
4	5	7.8	Bu
	9	7.8	Bu
	10	7.8	Ba
	10	7.8	M

R Draconis

Mo.	Day	Est.	Obs.
4	13	7.6	Bu
	17	7.8	S
	21	7.4	Bu
	22	7.9	O
	23	7.8	Ba
	27	7.9	Ba
	29	8.0	M
	29	8.0	Ma
	29	7.9	G
	30	8.0	Ba
5	1	7.8	Ly
	2	8.1	M

164055
S Draconis

Mo.	Day	Est.	Obs.
4	18	8.7	G
	23	8.5	G

164715
S Herculis

Mo.	Day	Est.	Obs.
4	23	11.3	Ba
	27	10.7	M

165631
RV Herculis

Mo.	Day	Est.	Obs.
4	26	13.8	M

170215
R Ophiuchi

Mo.	Day	Est.	Obs.
4	27	10.4	M
5	2	10.5	M

170627
RT Herculis

Mo.	Day	Est.	Obs.
5	2	12.8	Y

171723
RS Herculis

Mo.	Day	Est.	Obs.
4	24	12.4	Ba

175458
T Draconis

Mo.	Day	Est.	Obs.
4	25	11.0	Bu
	27	11.2	Ba
	30	11.0	M

175519
RY Herculis

Mo.	Day	Est.	Obs.
4	27	11.0	M
	27	11.0	Ba

180531
T Herculis

Mo.	Day	Est.	Obs.
4	5	7.6	P
	16	7.6	L
	22	7.8	L
	23	8.1	G
	23	7.9	P
	27	8.1	Ba
	27	8.3	M
	29	8.0	Ly
	30	8.1	M
5	1	8.4	Ly

181136
W Lyrae

Mo.	Day	Est.	Obs.
4	27	11.9	M
	27	12.2	Ba
	30	11.9	M

183308
X Ophiuchi

Mo.	Day	Est.	Obs.
4	21	8.8	L
	24	8.6	Ba

184205
R Scuti

Mo.	Day	Est.	Obs.
3	31	5.8	L
4	1	5.8	L
	5	5.8	L
	6	5.6	L
	10	5.5	L
	11	5.6	L
	16	5.4	L
	19	5.8	M
	21	5.2	L
	24	5.6	Ba

190108
R Aquilae

Mo.	Day	Est.	Obs.
4	16	9.6	L
	21	10.1	L

191019
R Sagittarii

Mo.	Day	Est.	Obs.
4	5	9.3	L
	21	8.4	L

191350
TZ Cygni

Mo.	Day	Est.	Obs.
4	2	10.8	L
	5	10.8	L
	17	10.9	L

193449
R Cygni

Mo.	Day	Est.	Obs.
3	31	6.6	L
4	3	6.8	Bb
	4	7.4	M
	6	6.7	Bb
	6	6.8	L
	10	6.8	L
	11	7.0	L
	13	6.8	Ba
	14	7.2	L
	19	8.0	M
	22	7.1	L
	24	7.1	Ba
	27	8.4	M
	27	7.2	L
5	2	8.4	M

193732
TT Cygni

Mo.	Day	Est.	Obs.
4	3	8.4	Bb
	10	7.3	L
	22	8.1	L
	23	8.0	P

194048
RT Cygni

Mo.	Day	Est.	Obs.
3	31	7.3	L
4	3	6.7	Bb
	4	7.6	M
	6	7.6	L
	10	7.6	L
	11	7.9	L
	13	8.0	Ba
	13	8.1	L
	14	8.0	L
	17	8.4	L
	19	8.1	M
	22	8.4	L
	24	8.2	Ba
	27	8.4	M
5	2	8.5	M

194632
χ Cygni

Mo.	Day	Est.	Obs.
3	31	11.8	L
4	3	11.0	Bb
	11	11.3	Bb
	23	10.4	P
	24	11.8	Ba

200212
SY Aquilae

Mo.	Day	Est.	Obs.
4	5	10.4	L
	16	10.1	L

200715a
S Aquilae

Mo.	Day	Est.	Obs.
4	27	10.5	M

200647
SV Cygni

Mo.	Day	Est.	Obs.
4	1	9.6	L
	10	9.6	L
	14	9.5	L
	19	9.1	M
	24	8.8	Ba
	27	8.9	M
5	1	9.2	Ly

200715b
RW Aquilae

Mo.	Day	Est.	Obs.
4	27	8.8	M

200938
RS Cygni

Mo.	Day	Est.	Obs.
4	2	8.2	L
	10	7.8	L
	22	8.2	L
	23	7.2	P

201521
RT Capricorni

Mo.	Day	Est.	Obs.
4	21	8.0	L

VARIABLE STAR OBSERVATIONS Apr.-May, 1914.

201647
U Cygni

Mo.	Day	Est.	Obs.
4	1	10.6	L
	10	10.5	L
	14	10.2	L
	19	9.4	M
	22	10.3	L
	24	8.6	Ba
	27	9.2	M

202539
RW Cygni

Mo.	Day	Est.	Obs.
4	2	9.1	Bb
	19	9.2	M
	23	9.2	P
	27	9.1	M

202946
SZ Cygni

Mo.	Day	Est.	Obs.
4	3	10.5	Ba
	18	9.7	Ba

SZ Cygni

Mo.	Day	Est.	Obs.
4	19	10.2	M
	23	9.5	P
	25	9.1	Ba
	27	9.0	M
5	2	9.6	Bb

210868
T Cephei

Mo.	Day	Est.	Obs.
3	31	10.0	L
4	2	10.0	L
	10	10.0	L
	13	10.0	Bu
	13	10.0	L
	16	10.0	L
	21	10.2	Bu
	23	9.8	P
	23	10.0	L

T Cephei

Mo.	Day	Est.	Obs.
4	24	9.6	Ba
	25	10.4	Bu
5	1	10.0	Ly

213044
W Cygni

Mo.	Day	Est.	Obs.
3	31	5.1	L
4	1	5.1	L
	5	5.2	L
	10	5.2	L
	11	5.2	L
	14	5.4	L
	16	5.2	L
	20	5.4	L

UU Cygni

Mo.	Day	Est.	Obs.
4	2	8.2	L
	6	8.2	L

UU Cygni

Mo.	Day	Est.	Obs.
4	10	8.0	L
	11	8.2	L
	16	8.5	L

213678
S Cephei

Mo.	Day	Est.	Obs.
4	24	10.0	Ba

213843
SS Cygni

Mo.	Day	Est.	Obs.
3	31	11.9	L
4	1	11.8	L
	2	11.8	L
	3	11.7	Bb
	6	11.8	L
	11	11.9	Bb
	16	11.9	L
	19	11.8	M

SS Cygni

Mo.	Day	Est.	Obs.
4	21	12.0	L
	22	12.0	L
	24	12.0	Ba
	27	12.0	M
	30	8.2	M
5	1	8.2	M
	2	8.3	M
	3	8.4	M
	7	8.4	M
	8	8.5	M

213937
RV Cygni

Mo.	Day	Est.	Obs.
4	6	6.3	L
	22	7.0	L
	23	7.5	P
	27	8.2	M

No. of observations, 1215; No. of stars observed, 143; No. of observers, 19.

The following calculated dates of maxima are taken from Dr. Hartwig's Catalogue:

April	4	083019	U Cancri
	7	194048	RT Cygni
	8	141964	S Boötis
	12	015354	U Persei— The "*English Mechanic*" cites Apr. 3
	14	160118	R Herculis
	14	043065	T Camelopardalis
	20	*120905*	T Virginis
	21	*085008*	T Hydrae
	21	141567	U Urs. Min.
	23	004047	U Cassiopeiae
	24	123961	S Urs. Maj.
	28	193449	R Cygni
	30	134440	R Can. Ven.
May	1	043274	X Camelopardalis The "*English Mechanic*" cites Apr. 8
	4	103769	U Urs. Maj.
	5	*122803*	Y Virginis
	8	142539	V Boötis
	10	064030	X Geminorum
	10	154615	R Serpentis

There are a number of cases in this report where misidentification of the variable is apparent from the wide variance in the estimates. Will members please check up their estimates carefully, and where they appear to differ widely from those of other observers special care should be used in future observations to correct these errors. These remarks do not apply where the variables in question are red stars.

The March issue of the B. A. A. Journal contains the interesting report of Mr. C. L. Brook, Director of the V. S. S. of the B. A. A. It affords an opportunity of comparing dates of maxima and magnitudes at maxima of the variables, the curves of which as drawn by Mr. Bancroft appeared in the April issue of POPULAR ASTRONOMY. The average variance in date was four days, while the average difference in magnitude at maximum was only 0.1 magnitude, a comparison most flattering to Mr. Bancroft.

The Secretary had the pleasure of meeeting in New York on the evening of April 8 with the following members of the Association:—Messrs. Barbour, Burbeck, Hunter, McAteer, Mills and Putnam. The evening was most enjoyably spent in discussing our common interest, and it was voted to meet annually if possible. It is hoped that future meetings will be attended by many other members. One of the best features of our organisation is this opportunity of meeting together. It promotes pleasant friendships and greatly stimulates interest in the work. In this utilitarian age it is rather unusual to find a group of men actively and eagerly engaged in a labor of love, and our Association has much to commend it apart from any considerations of an astronomical character.

The following members contributed to this report:—Messrs. Bancroft, Barbour, Bouton, Burbeck, Eaton, Gray, Hunter, Huntington, Jacobs, Lacchini, Lindsley, Mach, McAteer, Olcott, Putnam, Richter, Vrooman, Miss Swartz, Miss Young.

WILLIAM TYLER OLCOTT,
Corresponding Secretary.

Norwich, Ct. May 10, 1914.

GENERAL NOTES.

The next number of POPULAR ASTRONOMY will not be issued until about August 1.

We regret very much that Professor W. H. Pickering's Report on Mars has failed to reach us this month. Illustrations to go with the report were received more than a week before the number was closed.

Professor S. W. Burnham will retire from active service at the Yerkes Observatory on July 1, 1914, having been connected with that observatory for twenty-one years. Professor Burnham has devoted himself almost exclusively to the discovery and measurement of double stars, having discovered more than thirteen hundred doubles. His great catalogue containing measures of 13665 double stars, gathered from all available sources, is an indispensable reference book in all observatories.

Professor S. A. Mitchell, director of the McCormick Observatory at the University of Virginia, has been appointed Ernest Kempton Adams Research Fellow of Columbia University for 1914-15. Professor Mitchell is carrying on work in the measurement of stellar parallaxes by the photographic method. (*Science* April 24, 1914.)

Dr. Charles P. Olivier has been appointed to the position of adjunct professor of astronomy under Dr. Mitchell at the Leander McCormick Observatory of the University of Virginia.

Dr. F. W. Dyson, the astronomer royal for England, lectured before the Royal Institution on April 24 on the subject of "The Stars around the North Pole."

Dr. George William Hill, distinguished for his work in mathematical astronomy, died at his home in West Nyach, N. Y. on April 16, 1914, at the age of seventy-six years. A review of his life and work is being prepared by Professor F. R. Moulton, and will be published in the next issue of POPULAR ASTRONOMY.

Mr. Arthur Prahl, of Milwaukee, Wis., has recently been appointed director of the Nebula and Star Cluster section of the Society for Practical Astronomy, to succeed Mr. R. L. Doherty of Macon, Mo., who resigned.

Mr. Frederick C. Leonard lectured before the Mathematics club of the Wendell Phillips High School, Chicago, on January 16 on the subject "The Infinitude of the Universe", and on May 11 on "The Mathematical Discovery of the planet Neptune.

Members of the American Meteor Society are requested to send all reports and communications to the Leander McCormick Observatory, University of Virginia, Virginia, from this time on instead of to Agnes Scott College, Decatur, Georgia, as heretofore, since that will be my address in the future.

May 20, 1914. CHARLES P. OLIVIER.

The Solar Eclipse August 21, 1914.—So far as present reports indicate, the eclipse track for the total solar eclipse of August 20-21 next will be adequately covered at its different parts by a number of expeditions. Pulkova will establish three stations, one on an island in the Baltic, one at Kanev southeast of Kiev, and one at Feodosia in the Crimea. An expedition, under the auspices of the Joint Permanent Eclipse Committee of the Royal and the Royal Astronomical Societies, will be located at or near Kiev, the observers being Professor Fowler, Mr. W. E. Curtis, and Father Cortie, with Major Hills and Father O'Connor as volunteer observers. The Greenwich observers, Mr. Jones and Mr. Davidson, will be stationed at Minsk. A party from the Solar Physics Observatory, consisting of Professor Newall, Mr. Stratton, and Mr. Butler, will be located near Feodosia, near which spot will also be the camp of the expedition of the Cordoba Observatory under Dr. Perrine. There will probably be a number of observers in Sweden and others near Riga. The Lick Observatory Crocker eclipse expedition, under Dr. Campbell, with Dr. H. D. Curtis as associate, will probably be located near the small town of Brovary about ten miles north east of Kiev, as near as possible to the central line. Dr. Campbell will be accompanied by his family. The city of Hamburg is fitting out an expedition to be located at some point in Russia. An expedition headed by Professor Miethe of the Technological Institute of Charlottenburg will go to the island of Alston on the Norwegian coast, where the path of totality first touches the European continent. (*Pub. Astron. Soc. of the Pacific*, April, 1914.)

Few Variables Among the Very Faint Stars.—At the April meeting of the Royal Astronomical Society in London Mr. C. R. D'Esterre, while exhibiting a number of photographs of the region of Nova Persei, remarked upon the very few variable stars which have been found among the very faint stars. He says: "The general conclusion with regard to all the regions I have under observation is, that there are practically no variables among the very faint stars. It appears as though when we move out towards the confines of our universe we leave behind the region —and perhaps the cause—of variable stars."

Table for Calculating the Combined Magnitude of a Double Star. In "*The Observatory*" for May 1914 Mr. T. Lewis gives an interesting paper on Magnitudes," in a series which he is writing on "Double Star Astronomy", from which we extract the following useful table. In this table m is the magnitude of the brighter component of a double star, $m+d$ that of the fainter component and c their combined magnitude. Given two of these quantities the third may be found from the table.

d	$m-c$	d	$m-c$
0.0	.75	1.1	.33
.1	.70	1.2	.31
.2	.66	1.3	.29
.3	.61	1.4	.26
.4	.57	1.5	.24
.5	.53	2.0	.20
.6	.49	2.5	.08
.7	.46	3.0	.06
.8	.42	4.0	.03
.9	.39	5.0	.01
1.0	.36		

For example, the components of ζ Herculis are 3 and 6, what is their combined magnitude?

Here $d = 3.0$; hence, looking in column $m - c$, opposite $d = 3.0$, we find .06. Since $m = 3.00$, $c = 3.00 - 0.06 = 2.94$.

Again, if the combined magnitude of the two components of κ Pegasi is 3.8 and the magnitude of the principal star is 4.3, what is the magnitude of the fainter component? Here $m - c = 0.5$ and the corresponding value of d in the table is 0.6; the magnitude of the fainter star is therefore $4.3 + 0.6 = 4.9$.

Publications of the U. S. Naval Observatory.—The Naval Observatory has just issued Volume VIII, Second Series, of its publications. The last previous issues in this series were Volume VI and VII which appeared in 1911. The Observatory has in hand and nearing completion the material for a volume in three large parts, of meridian circle work, and also the material for a volume in two parts, of prime vertical work. The volume just issued comprises the vertical circle observations made with the alt-azimuth instrument from 1898 to 1907 and the resulting declinations of the Newcomb standard stars. The alt-azimuth instrument is the only one of its kind in this country, having been constructed by the Warner and Swasey Company in accordance with the designs of the late Professor Wm. Harkness, U.S.N. The observations were made by Professor F. B. Littell, U.S.N., Assistant Astronomer G. A. Hill, and Assistant H. B. Evans.

Publications of the Lick Observatory.—Volume VII of the Publications of the Lick Observatory, which has just come to hand, is a large volume containing ten valuable papers, all of which are "Contributions of the Berkeley Astronomical Department, University of California." The titles of the ten parts are as follows:

1. A short method of determining orbits from there observations. A first paper by A. O. Leuschner.
2. Elements of Asteroid 1900 GA, by A. O. Leuschner and Adelaide M. Hobe.
3. Preliminary elements of Comet 1900 III, by R. H. Curtiss and C. G. Dall.
4. Tables for the reduction of photographic measures, by Burt L. Newkirk.
5. Investigation of the Repsold measuring apparatus, by Burt L. Newkirk.
6. On astronomical refraction, by R. T. Crawford.
7. Short methods of determining orbits. Second paper, by A.O. Leuschner.
8. Applications of Leuschner's short method of determining orbits, by R. T. Crawford.
9. Short methods of determining orbits. Third paper: The direct solution of orbits of disturbed bodies, by A. O. Leuschner.
10. Direct solution of preliminary disturbed orbits of the seventh and eighth satellites of Jupiter, by Leuschner's method, by R. T. Crawford.

The Right Strength of the Fixing Bath.—Many are very careless about the proportions of the fixing bath, throwing any amount of crystals into an unmeasured amount of water. The following from *The British Journal of Photography* indicates that there is a proportion which gives a maximum rapidity of fixation:

"A year or so ago we published an article on the speed of fixing, by Mr. C. Welborne Piper, in which the author showed that a bath containing eight ounces of hypo to the pint (40 per cent) fixed more rapidly than baths of either less or greater concentration. Since then we have put the matter to a practical test with plates of various brands, and there appears to be no room for doubt that the same conditions apply to various emulsions with very close accuracy. During the recent cold weather, with tap water and fixing bath down to between 40 and 50 degrees F., a 40 per cent bath worked as rapidly as could be wished, the plates being clear in a very few minutes. So far as we can see this rapid fixing has no disadvantage whatever to counterbalance its very obvious advantages, and we certainly consider that 40 per cent should now be looked upon as the right strength for a plate fixing-bath. It is true it requires twice as much hypo as the usual 20 per cent bath, but it saves considerably more than half the time, and time is a far more valuable consideration than the cost of hypo to the practical worker." (*The British Journal of Photography* Feb. 20, 1914.)

The Age of the Earth.—Certain colored minerals, in particular certain micas when examined microscopically, present dark stains in the form of a disk At the center of each stain is a little crystal, usually a crystal of zircon which has been included at the moment of formation of the mica. The explanation of these dark stains is to be found in the fact that the zircons are strongly radio-active. The radio-active crystals stain the mica in the same way as they color glass, etc. But the X-rays emitted by different radio-active substances have not all the same penetrating power, and for that reason the mica stains are usually darkest at the center. If they are old enough the stain is uniformly dark, as even the few rays which reach the outer part had time to completely stain it. Experiments were made by Joly and Rutherford to determine experimentally the number of X-rays required to produce a given stain in mica. Measurements were made on the halos or stains so produced and

they were compared with those produced naturally by the zircon crystals. The amount of uranium present in the crystal was evaluated and the number of X-rays necessary to produce the natural stain permitted one to ascertain the amount of uranium which must have disintegrated since the origin of the mineral. The theory of radio-active transformations then leads very simply to an expression for the age of the halo. The numbers obtained oscillated between 470 million and 20 million years, which is in fair agreement with the determinations of the age of rocks, although they differ from the results which have been deduced from the quantity of salt contained in the oceans. (*Scientific American*, March 7, 1914.)

Sunspots and the Leonids.—Professor Turner has been engaged for some time in analyzing Wolfe's sun-spot numbers in a Fourier sequence, "arriving finally at the conclusion that none of the periodicities disclosed were continuous throughout the series." In the present paper, he resumes the discussion, beginning by describing a simple expedient for detecting the breaks in such a series. The method followed is exhibited in a detailed application to Wolfe's numbers from 1749 on, which reveals discontinuities or breaks in the series, not introduced by the calculation and hence existing in the observational data. "These breaks are near the dates 1766, 1796, 1838, 1868, 1895, which are sufficiently close to those of *Leonid* perihelia to suggest a *vera causa*."

Before discussing this hypothesis the author exhibits a table to show varying periods which best fit the sun-spot numbers. These are as follows: 1749-1767, 10.9 years; 1760-1796, 9.379; 1787-1838, 12.49; 1829-1870, 11.69; 1860-1894, 12.07; 1890-1911, 13.39.

The remaining portion of the paper is devoted to an exposition of his hypothesis that the *Leonid* meteor swarm is responsible for these discontinuities, or changes of period in sun-spot activity.

The *Leonids* cannot act directly, since the perihelion distance of the stream is about an astronomical unit; hence a secondary swarm is postulated. This swarm is assumed to revolve in about eleven years, with a very small perihelion distance, comparable to the Sun's radius. The major axis of the orbit is nearly five astronomical units, and the eccentricity is exceedingly high, $e = 1 - .001$. Hence, on any ordinary sized diagram, the orbit would be practically a straight line, resting one end on the Sun, with the other extending 10 A. U., approximately *Saturn's* distance, from the Sun. In such an orbit the velocity at the Sun end would be very great, at the other very small; hence the swarm would linger at aphelion, four fifths of the period being spent at a distance greater than 5 A. U. from the sun, and half the period at a distance exceeding 8.5 A. U.

In this part of the orbit the swarm will be very sensitive to perturbations, and it is suggested that the *Leonid* swarm is the disturbing agent. This assumption is then investigated in detail, the perturbing effect of the *Leonids* on the swarm as it moves out toward aphelion and, later, when it returns, being taken into account.

Professor Turner finds that by plausible assumptions of the relative positions of the hypothetical swarm and of the *Leonids*, the observed variation in periods can be explained.

The origin of this hypothetical swarm is then considered and the hypothesis is advanced that it is a portion of the *Leonid* swarm which has been detached by an encounter of the *Leonids* with *Saturn*. From a consideration of the periods of *Saturn* and of the *Leonids*, it is found that the year 301 A. D. "seems most promising" for this encounter, though there are also arguments in favor of the year 271 A. D.

The author admits that "the foregoing theory depends on the fundamental assumption that the *Leonids* have suffiicient mass to alter the period of the SSS [sun-spot swarm] very considerably. If so, they must also be able to perturb appreciably other bodies near which they pass, and particularly the earth." The unexplained fluctuations in the Moon's motion are then examined and the conclusion is reached that they are quite consistent with disturbances at *Leonid* returns.

Professor Turner further thinks it possible that the *Leonids* may be responsible for the unexplained secular movement of the perihelion of *Mercury*.

Finally, he finds no difficulty in accounting for the "equatorial acceleration" of sun-spots.

At the time of making this abstract no critical comment on Professor Turner's hypothesis has been printed.

R. G. AITKEN in *Pub. Astron. Soc. of the Pacific* April 1914.

On the Total Light of the Stars.—In the *Monthly Notices* of the Royal Astronomical Society for March 1914 Mr. S. Chapman, of the Royal Observatory at Greenwich, gives an interesting paper in which he calculates that the total light of all the stars is equivalent to that from about 700 stars of the first magnitude (photographic). A single star which would give as much light as all the stars would be of magnitude —6.1. The full moon gives 100 times as much light as all the stars together.

The formula for the number N_m of stars brighter than a given magnitude m, as derived by Mr. Chapman and Mr. P. J. Melotte, who worked with him in the investigation, is

$$N_m = A \frac{1}{\sqrt{\pi}} \int_{-\infty}^{B(m+C)} e^{-x^2} dx ,$$

in which the constant A represents the total number of stars and C the magnitude to which it is necessary to go in order to obtain half the total number of stars. A, B, C are connected with other constants a, b, c occuring in the formula

$$\log \frac{dN_m}{dm} = a + bm - cm^2,$$

by the relations

$$A = \sqrt{\frac{\pi \log_{10} e}{c}}\ 10^{a + \frac{b^2}{4c}}, \quad B = \sqrt{\frac{c}{\log_{10} e}}, \quad C = \frac{b}{2c}.$$

The constants a, b, c were determined from observed data, and from them were found values of A, B and C. Four different sets of computations gave for A values ranging from 760 million to 3000 million. The magnitude C, down to which we must go to get half the total number of stars ranged from 22.5 to 25.4. It thus appears that the most powerful telescopes which are in existence cannot reveal anywhere near half of the total number of stars.

For the combined intensity I_m of the light received from all the stars the adopted formula was

$$I_m = J.A' \frac{1}{\sqrt{\pi}} \int_{-\infty}^{B'(m - C')} e^{-x^2} dx$$

where

$$A' = \sqrt{\frac{\pi \log_{10} e}{c}} \cdot 10^{a + \frac{(b-0.4)^2}{4c}}, \quad B' = B, \quad C' = \frac{b-0.4}{2c}.$$

Here A' represents the intensity of the light from all the stars and C' is the magnitude to which it is necessary to go in order that the combined intensity of all stars brighter than this limit shall equal half that of all stars. The value of C' comes out $10^m.0$ in all four sets of computations, while A' ranges only from $10^{2.380}$ to $10^{2.396}$.

The approximate results of the computations are given in the following table, in which the first column gives the range of magnitude, the second the number of stars in each range of one magnitude, the third the number of stars of magnitude 1.0 which would give an equivalent amount of light, and the fourth column the totals of the numbers in the third column down to each magnitude.

THE EQUIVALENT LIGHT OF THE STARS.

Magnitude	Number	Equivalent number of 1st magnitude stars.	Totals to magnitude
			m
—1.6	Sirius	11	...
—0.9	α Carinæ	6	...
0.0	α Centauri	2	...
0.0—1.0	8	14	33
1.0—2.0	27	17	50
2.0—3.0	73	18	68
3.0—4.0	189	19	87
4.0—5.0	650	26	113
5.0—6.0	2,200	35	148
6.0—7.0	6,600	42	190
7.0—8.0	22,550	56	246
8.0—9.0	65,000	65	311
9.0—10.0	174,000	69	380
10.0—11.0	426,000	68	448
11.0—12.0	961,000	60	508
12.0—13.0	2,020,000	51	559
13.0—14.0	3,960,000	40	599
14.0—15.0	7,820,000	31	630
15.0—16.0	14,040,000	22	652
16.0—17.0	25,400.000	16	668
17.0—18.0	38,400,000	10	678
18.0—19.0	54,600,000	6	684
19.0—20.0	76,000,000	3	687
All stars fainter than $20^m.0$		3	690

It is readily seen from this table that the stars which are below the limit of vision to the naked eye send us between three and four times as much light as those which are visible to the unaided eye. The groups which give us most light are those of magnitudes 9.0—10.0 and 10.0—11.0. On the other hand, half of the total light of the stars comes from those brighter than magnitude 10.0, three fourths from those brighter than 12.0 and seven eighths from those brighter than 14.0 while all the stars fainter than magnitude 20, numbering several hundreds of millions, yield less than half of one per cent of the total starlight which reaches us.

Expressed in another way, the total light of all the stars is equivalent to that of about 1750 stars as bright as Polaris, or 60 as bright as Sirius. Again, its photographic intensity is equal to that of a 1-candle power lamp at 10.8 metres (11.8 yards) distance, or to that of an ordinary 16-candle power lamp at 47 yards distance.

The Essence of Astronomy.—Things every one should know about the sun, moon, and stars. By Edward W. Price. G. P. Putnam's Sons, New York and London. 1914. Price $1.00, net.

This is a neatly printed and bound book of 207 12 mo pages, intended for the general reader. It is essentially a brief compilation, in simple language, of the facts of astronomy, the material being so arranged that it is readily available for quick reference as well as for interesting consecutive reading. The illustrations are excellent, most of them being reproductions, on fine plate paper, of photographs taken at the Yerkes, Lick and Lowell Observatories. A chronological table of astronomical events, given at the end of the book, is an interesting feature, but at a hasty glance we note some errors which mar its usefulness. For example in the last item; Eros, the nearest planetoid, was discovered in 1898 instead of 1908.

Celestial Mechanics.—Those interested in the study of Mathematical Astronomy will be pleased to know that a new edition of the text book Celestial Mechanics by Professor F. R. Moulton has recently been issued. For several years it was impossible to secure a copy of this book because the first edition had been exhausted. The need for this new edition was therefore keenly felt. In preparing the work for the new edition, the author took the opportunity of thoroughly revising it. Throughout the book the author has kept prominently before him the purpose of making the discussions sufficiently simple and clear to enable the student who is beginning the study of mathematical astronomy to read it with comprehension and profit. The book begins with a statement and discussion of the fundamental principles of mechanics. Following are chapters in order on Rectilinear Motion, Central Forces, The Potential and Attractions of Bodies, The Problems of two Bodies, The Determination of Orbits, The General Integrals of the Problem of n Bodies, The Problem of Three Bodies, Perturbations—Geometrical Considerations, Perturbations—Analytical Method.

The revised book is somewhat larger than the original one, due to further elaboration of various topics rather than to the introduction of any essentially new material. The book, because of its simple and yet rigorous presentation of the leading considerations in the study of Celestial Mechanics, fills a unique place among treatises of this kind, and now that it is again obtainable in the revised form will doubtless find its way into many more schools than before.

It is published by the Macmillan Company, 66 Fifth Ave, New York, and the price of it is $3.50.

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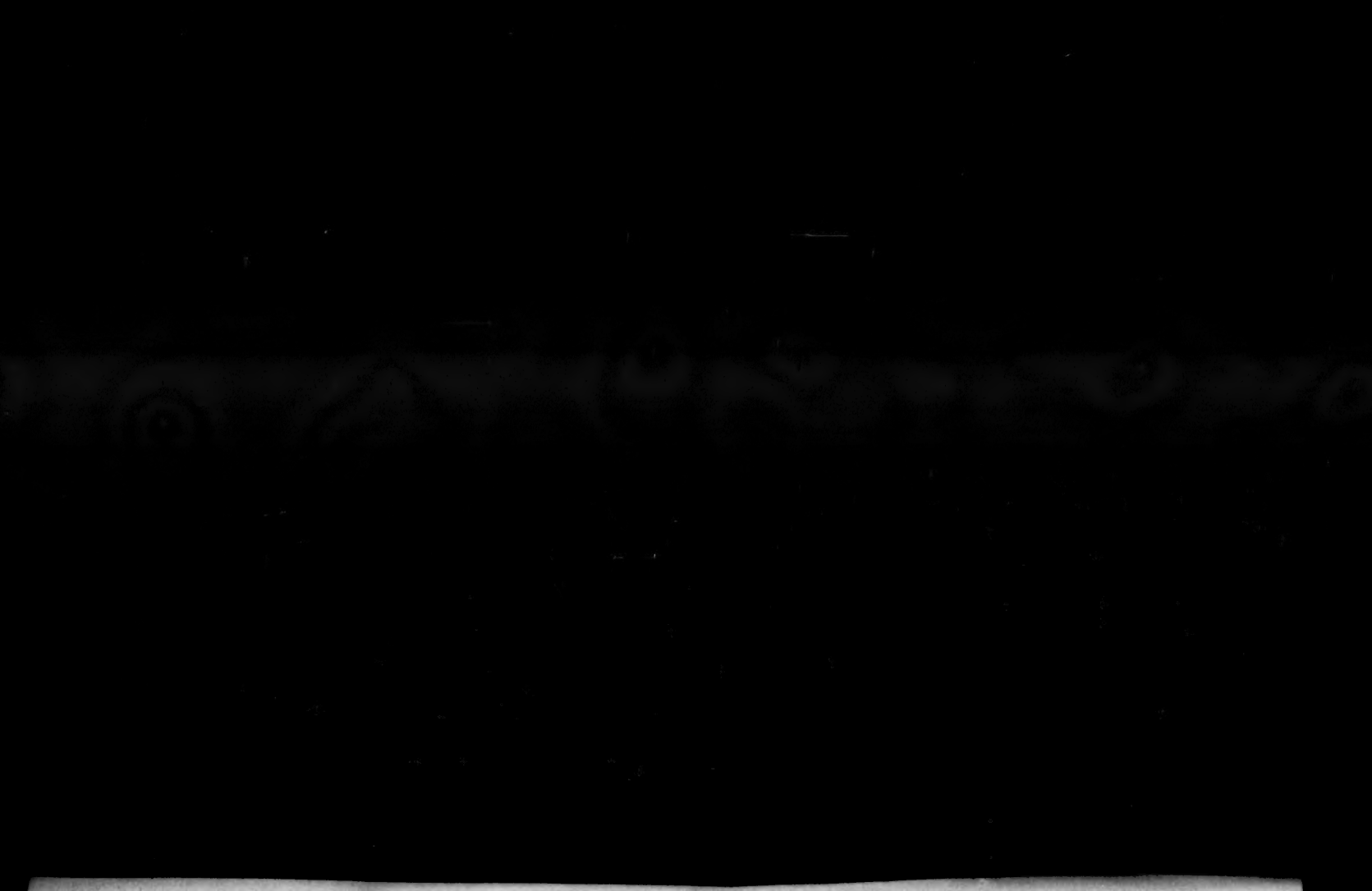
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